U. S. DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES

PROGRESS IN BIOLOGICAL INQUIRIES 1931

By ELMER HIGGINS

U. S. DEPARTMENT OF COMMERCE
ROY D. CHAPIN, Secretary
BUREAU OF FISHERIES
HENRY O'MALLEY, Commissioner

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APPENDIX III TO REPORT OF COMMISSIONER OF FISHERIES FOR THE FISCAL YEAR 1932

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PROGRESS IN BIOLOGICAL INQUIRIES, 1931 [1]

By ELMER HIGGINS, *Chief, Division of Scientific Inquiry*

[With the collaboration of investigators]

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[1] Appendix III to the Report of the U. S. Commissioner of Fisheries for 1932. Approved for publication, June 16, 1932

INTRODUCTION

Fisheries biological research by the bureau's division of inquiry respecting food fishes was conducted during the year 1931 under ideal conditions. Not only were funds provided in adequate measure to meet the ordinary needs of the existing organization, but the effects of the economic depression had not yet seriously interfered with the law of supply and demand regulating fishing activities, nor during the early part of the year had it greatly increased the strain upon the fishes of interior waters. Under such circumstances a large staff, functioning with high efficiency, succeeded in collecting great numbers of field observations, which by the end of the year were rapidly being analyzed as a basis for a number of technical reports. All of the major projects under way during 1930 were continued, many of the minor ones were completed, and two entirely new projects of considerable importance were undertaken.

The chief functions of the Bureau of Fisheries are concerned with the conservation of our aquatic resources, yet its operations are different from those of other similar governmental units. Virtually all of the State governments maintain fishery boards, fish and game departments, or conservation commissions, all of which give direct attention to the problems of conservation through regulation of the fisheries by rule or by the enforcement of laws enacted by the State legislatures. Their functions are chiefly administrative, although a few States engage in research as a basis for their regulatory activities. Foreign Governments likewise maintain fishery departments that correspond to our State commissions in their regulatory and administrative functions.

Federal activities in fishery conservation in the United States, however, are of the positive kind, looking toward the development and complete utilization of aquatic resources by means of scientific research and practical fish culture, rather than by negative or restrictive activities such as are involved in the enforcement of regulatory legislation. Except in the Territory of Alaska, the Bureau of Fisheries is without power to regulate fishing, for under the Federal form of government Congress enjoys only such powers as are delegated by the Constitution, and complete jurisdiction of the fisheries has remained in the hands of the individual States. The Bureau of Fisheries is, therefore, essentially a scientific organization; and its findings, presented to the States in the form of technical reports and direct recommendations, become effective only by enactment of the State legislatures. Such recommendations, however, based upon adequate scientific studies and coming from a disinterested and impartial source, are cordially accepted by the States and have great influence in shaping conservation policies insuring the perpetuation of our aquatic resources.

Research activities in the biological sciences are conducted by the technical staff of the division, numbering some 50 permanent research positions, with a score of less trained assistants and perhaps another score of temporary specialists, chiefly from university faculties, who are employed for limited periods of time. These investigators are distributed over the entire country in small groups organized into compact research units, which maintain headquarters either at the

bureau's biological or experimental stations or at universities. Only a small administrative staff in the office of the chief of the division is located at Washington, D. C. A half dozen or so investigators whose duties require their location there are accommodated in the new laboratories of the Department of Commerce building.

The scientific projects cover three major fields: Marine and fresh-water commercial fisheries investigations, investigations pertaining to game fishes, and shell-fisheries investigations. Commercial fishery investigations are organized under six distinct sections, each with a responsible technical head. The North Atlantic fishery investigations, directed by O. E. Sette, are conducted from headquarters located at the Harvard Biological Institute, Cambridge, Mass., the Woods Hole Biological Laboratory serving as headquarters during the summer season only. The South Atlantic staff is housed at the Fisheries Biological Laboratory, Beaufort, N. C., under the direction of Dr. H. F. Prytherch. Investigations in the Gulf, directed by Dr. F. W. Weymouth, chiefly concerned with the great shrimp fishery, are conducted from headquarters provided by the Conservation Department of Louisiana at New Orleans. Fishery investigations in interior waters, under Dr. M. M. Ellis, including studies of pollution of the Mississippi River system and the propagation of fresh-water pearl mussels, are facilitated by laboratories provided by the University of Missouri, Columbia, Mo. Great Lakes fishery investigations, directed by Dr. John Van Oosten, are centered at the University of Michigan, Ann Arbor. The staff for the Pacific coast and Alaska fishery investigations, directed by Joseph A. Craig, is housed at the new Fisheries Biological Laboratory, Seattle, which was completed during the past year and is adjacent to the campus of the University of Washington.

Although the division of scientific inquiry conducts no investigations directly concerned with angling, a considerable amount of attention is given to problems of interest to the angler inasmuch as they concern the food and game fishes of interior waters, their culture, distribution, and their planting in depleted or formerly barren waters.

These investigations are of various types. The original distribution and taxonomic distinctions of the Salmonidæ of New England have been investigated by Dr. W. C. Kendall. While the chief investigator in aquiculture, Dr. H. S. Davis, is located in Washington, D. C., studies under his direction in the interest of fish culture, pathology of fishes, fish nutrition, and selective breeding are conducted at the Fisheries Biological Laboratory, Fairport, Iowa, at the experimental trout hatchery, Pittsford, Vt., at the experimental trout and bass station at Leetown, W. Va., and at certain cooperative stations where facilities are provided. Headquarters for trout-cultural investigations and stream surveys conducted by Dr. A. S. Hazzard in the national parks and forests of the Rocky Mountain region are maintained at the University of Utah, Salt Lake City, while California trout investigations carried on by Allan C. Taft are centered at Stanford University.

As a by-product of studies on the life history of fishes in Chesapeake Bay, John C. Pearson produced a popular Fishery Circular on the sport fishing in those waters.

The chief oyster investigator, Dr. Paul S. Galtsoff, is also located in Washington, but field laboratories have been established at Milford, Conn., and a cooperative laboratory for oyster research on Puget Sound is furnished by the State of Washington at Olympia. Research is conducted on the physiology of oysters at the Woods Hole (Mass.) laboratory during the summer months, and the studies on oyster culture in the South Atlantic area are also under the technical supervision of the chief oyster investigator.

Studies of the razor clam in Alaska were conducted independently by investigators temporarily detailed to that work.

During the past year the division has operated a number of vessels, launches, and floating laboratories in the conduct of its scientific investigations. Various phases of the North Atlantic fisheries investigations have required the full time of the *Albatross II*, a 150-foot steam vessel equipped for oceanographic work and experimental trawling. The *Phalarope*, a 110-foot steam yacht, and a chartered power boat in New Jersey have also been employed part time. Fishery studies in Lake Michigan have been prosecuted from the motor ship *Fulmar*, a 102-foot vessel equipped for experimental fishing and limnological studies. An able 38-foot cabin motor cruiser and various smaller launches are stationed at the Beaufort (N. C.) laboratory and two seagoing launches, 45 and 65 feet, respectively, are used by the shrimp investigators of the Gulf. On the Mississippi River two house boats and various launches provide laboratory and collecting facilities, one an 85-foot quarter boat on the lower river houses Doctor Ellis's staff of a dozen coworkers and has a large, well-equipped physiological and chemical laboratory, and another 50 feet long is stationed in the Upper Mississippi Wild Life and Fish Refuge for limnological work. In Alaska a 45-foot launch is used exclusively for herring investigations and various others of the bureau's fleet of vessels are employed as circumstances warrant.

In order to bring before the public certain research activities closely related to the bureau's studies of the Pacific salmon, the work undertaken at odd times during the last 12 years by Dr. Henry B. Ward, of the University of Illinois, should be mentioned. At intervals during the summers since 1918 Doctor Ward has been engaged in research on problems related to the migration of the sockeye salmon supported by funds of the bureau but conducted independently of the division of scientific inquiry.

These studies, while of great interest scientifically, have produced results that promise considerable practical application, especially since the salmon, an anadromous species, is produced in a region where the interests of conservation and hydroelectric power development have been and will continue in violent conflict.

The nature of these studies by Doctor Ward is indicated by the following titles, which are recommended to the critical attention of fishery students and conservationists:

Some features in the migration of the sockeye salmon and their practical significance. Proceedings of the American Fisheries Society for 1920, pp. 387–426.

Some of the factors controlling the migration and spawnings of the Alaska red salmon. Ecology, vol. 2, No. 4, October, 1921.

The influence of a power dam in modifying conditions affecting the migration of salmon. Proceedings of the National Academy of Sciences, vol. 13, No. 12, December, 1927, pp. 827–833.

Further studies on the influence of a power dam in modifying conditions affecting the migration of the salmon. Proceedings of the National Academy of Sciences, vol. 15, No. 1, January, 1929, pp. 56–62.

Some responses of sockeye salmon to environmental influences during fresh-water migration. Annals and Magazine of Natural History, 10th series, vol. 6, No. 31, 1930, pp. 18–36.

The division also maintains contact with the research program of the fisheries of the North Atlantic and progress in biological investigations relating to these fisheries conducted by the various Governments concerned through the annual meetings of the North American Council on Fishery Investigations—an international scientific advisory body composed of representatives of Canada, Newfoundland, France, and the United States. The eighteenth meeting of this organization was held on September 29 and 30, 1931, at Ottawa, at which the United States was represented by the chairman, Dr. Henry B. Bigelow; by Henry O'Malley, Commissioner of Fisheries; and by Elmer Higgins, chief of the division of scientific inquiry.

The division also maintains contact with the research program of the International Passamaquoddy Fisheries Commission, engaged in studies of the Passamaquoddy region, the coastal waters of Maine, and the Bay of Fundy, with special reference to the probable effect upon the fisheries of projected hydroelectric development at the mouth of Passamaquoddy Bay. O. E. Sette, in charge of the division's North Atlantic fishery investigations, is one of the United States commissioners, and a technical advisory committee to the commission includes Dr. Henry B. Bigelow and Prof. A. E. Parr, both of whom are engaged in cooperative researches with the division's staff. Several meetings of this commission during the year have been attended by these gentlemen and on occasion by the chief of the division acting for the Commissioner of Fisheries.

During the year 21 scientific or administrative reports were published under the supervision of the division or as a result of investigations of its staff. The list of papers follows:

CHAMBERLAIN, THOMAS K.

Annual growth of fresh-water mussels. Bulletin, Vol. XLVI, 1930, pp. 713–739, 20 figs. Document 1103.

COWLES, R. P.

A biological study of the offshore waters of Chesapeake Bay. Bulletin, Vol. XLVI, 1930, pp. 277–381, 16 figs. (graphs only). Document 1091.

ELLIS, M. M.

A survey of conditions affecting fisheries in the upper Mississippi River. Fishery Circular No. 5, 18 pp.

Some factors affecting the replacement of the commercial fresh-water mussels. Fishery Circular No. 7, 10 pp.

ELLIS, M. M., AMANDA D. MERRICK, and MARION D. ELLIS.

The blood of North American fresh-water mussels under normal and adverse conditions. Bulletin, Vol. XLVI, 1930, pp. 509–542, 14 figs. Document No. 1097.

FEDERIGHI, HENRY.

Studies on the oyster drill (*Urosalpinx cinerea*, Say). Bulletin, Vol. XLVII, pp. 85–115, 7 figs. Bulletin No. 4.

GALTSOFF, PAUL S.

Survey of oyster bottoms in Texas. Investigational Report No. 6, 30 pp., 14 figs., 1 map.

GALTSOFF, PAUL S., and DOROTHY V. WHIPPLE.

Oxygen consumption of normal and green oysters. Bulletin, Vol. XLVI, pp. 489–508. Document No. 1094.

GINSBURG, ISAAC.
Juvenile and sex characters of *Evorthodus lyricus* (Fam. Gobiidæ). Bulletin, Vol. XLVII, pp. 117–124, 2 figs. Bulletin No. 5.
GUTSELL, JAMES G.
Natural history of the bay scallop. Bulletin, Vol. XLVI, 1930, pp. 569–632, 32 figs. Document No. 1100.
HIGGINS, ELMER.
Progress in biological inquiries, 1929. Appendix XV, Report, Commissioner of Fisheries, 1929, pp. 1069–1121, 11 figs. Document No. 1096.
Progress in biological inquiries, 1930. Appendix III, Report, Commissioner of Fisheries, 1931, pp. 553–626, 8 figs.
HOPKINS, A. E.
Temperature and shell movements of oysters. Bulletin, Vol. XLVII, pp. 1–14, 10 figs. Bulletin No. 1.
HOPKINS, A. E.
Factors influencing the spawning and setting of oysters in Galveston Bay, Tex. Bulletin, Vol. XLVII, pp. 57–83, 18 figs. Bulletin No. 3.
HOPKINS, A. E., PAUL S. GALTSOFF, and H. C. MCMILLIN.
Effects of pulp-mill pollution on oysters. Bulletin, Vol. XLVII, pp. 125–186, 50 figs. Bulletin No. 6.
PEARSON, J. C.
Sport fishing in Chesapeake Bay. Fishery Circular No. 1, 19 pp., 11 figs.
RICH, WILLIS H., and EDWARD M. BALL.
Statistical review of the Alaska salmon fisheries, part 2: Chignik to Resurrection Bay. Bulletin, Vol. XLVI, 1930, pp. 643–712, 11 figs. Document No. 1102.
ROUNSEFELL, GEORGE A.
Fluctuations in the supply of herring (*Clupea pallasii*) in southeastern Alaska. Bulletin, Vol. XLVII, pp. 15–56, 26 figs. Bulletin No. 2.
SETTE, O. E.
Outlook for the mackerel fishery in 1931. Fishery Circular No. 6, 20 pp., 4 figs.
WEYMOUTH, F. W., and H. C. MCMILLIN.
Relative growth and mortality of the Pacific razor clam (*Siliqua patula*, Dixon) and their bearing on the commercial fishery. Bulletin, Vol. XLVI, 1930, pp. 543–567, 11 figs. Document No. 1099.
WEYMOUTH, F. W., and SETON H. THOMPSON.
The age and growth of the Pacific cockle (*Cardium corbis*, Martyn). Bulletin, Vol. XLVI, 1930, pp. 633–641, 7 figs. Document No. 1101.

In addition to these papers, the following were published by the staff during the past year in other than the bureau's series.

FIRTH, F. E.
A note on spawning rosefish, *Sebastes marinus* L. Copeia, No. 2, p. 65.
Some marine fishes collected recently in New England waters. Bulletin, Boston Society of Natural History, No. 61, pp. 8–14.
Rare fishes from off North Carolina. Copeia, No. 4, p. 162.
GALTSOFF, P. S.
The weight-length relationship of the shells of the Hawaiian pearl oyster, Pinctada sp. American Naturalist, Vol. LXV, pp. 423–433.
Specificity of sexual reaction in the Genus Ostrea. Collecting Net, Vol. VI, pp. 277–278.
HERRINGTON, W. C.
The Bureau of Fisheries haddock investigation. Fishing, Vol. XI, No. 2, pp. 12, 47–49.
KOEHRING, VERA.
Thermal relationships in the neutral-red reaction, 1931. Journal Morphology and Physiology, vol. 52, No. 1, pp. 165–194.
PRYTHERCH, HERBERT F.
The rôle of copper in the setting and metamorphosis of the oyster. Science, April 17, 1931, vol. 73, No. 1894, pp. 429–431.
The U. S. Fisheries Biological Station at Beaufort, N. C. Collecting Net, August 29, 1931, pp. 257–260.

SCHROEDER, W. C.
Notes on certain fishes collected off the New England coast from 1924 to 1930. Bulletin, Boston Society of Natural History, No. 58, pp. 3–8.
An account of the fishes dredged by the *Albatross II* along the continental slope south of New England in February and March, 1929. Copeia, No. 2, pp. 41–46.
SETTE, O. E.
Research ship for the U. S. Bureau of Fisheries. Fishing, Vol. XI, No. 10, pp. 9–11.

In previous reports mention has been made of extensive cooperation in fisheries research by States and other institutions. Such cooperation has been continued, and even extended, to a most gratifying degree during the past year. Not only has official support and encouragement in specific projects been accorded by the States, but active participation, either through the furnishing of considerable funds or by coordinated activities on the part of the research staffs of the individual State fish and game commissions, has been undertaken to such an extent that activities of the bureau's staff have been more effective and extensive than would have been the case otherwise. Such cooperation, which is gratefully acknowledged by the bureau, is in most cases mentioned in connection with the various investigations in the following pages.

The following progress reports covering the more important investigations of the division during the calendar year 1931 were prepared in the main by the investigators in charge of the various projects.

NORTH AND MIDDLE ATLANTIC FISHERY INVESTIGATIONS

Studies of important food fishes of the Atlantic coast north of Cape Hatteras continued during 1931 to obtain much needed information on the effects of natural conditions and commercial exploitation on the abundance of cod, haddock, mackerel, squeteague, scup, butterfish, and winter flounders. The scientific staff has had its headquarters at Cambridge, Mass., where the Museum of Comparative Zoology and the Biological Laboratories of Harvard University have generously provided laboratory and library facilities. This association with the university has facilitated consulation with members of the faculty when advice was needed in special phases of zoology, physiology, chemistry, physics, and oceanography; and specially valuable has been the counsel of Dr. Henry B. Bigelow, professor of oceanography at Harvard University and director of the Woods Hole Oceanographic Institution. The continued cooperation of Prof. A. E. Parr, curator of the Bingham Oceanographic Foundation at Yale University, in directing and conducting studies of the early life histories of fishes along the coast of New Jersey has been an invaluable supplement to the studies of the commercial fisheries of that region. The New York aquarium has also kindly assisted in the work by making collections of young fishes with its station vessel, the *Sea Horse*, and many courtesies have been extended by the Woods Hole Oceanographic Institution and the Marine Biological Laboratory at Woods Hole. The cooperation of these various organizations, the friendly willingness of fishermen to give information on their fishing operations, in some cases expending considerable effort in the keeping of log-book records, and the kindness of fishing companies

in putting business records at the disposal of our staff and providing facilities for them on board their vessels and in their shore establishments, which have made possible the progress reported in the following sections, is gratefully acknowledged.

HADDOCK

The investigation of the haddock fishery has been carried on during 1931 by several investigators under the immediate direction of W. C. Herrington.

Statistical and biological studies of the haddock population.—During the past two years the haddock fishery of New England has experienced a sharp decline, following a period of exceptional productiveness. On the fishing grounds, principally Georges Bank and South Channel, where the bulk of the United States landings have originated during the past few years, the abundance of haddock, as measured by the average catch per trawler per day's fishing, increased markedly from 1924 to a maximum in 1927. Since then it has fallen off sharply to a level in 1930 far below that in 1924. This drop continued during the first half of 1931.

The decline beginning in 1928 did not at first seriously affect the fishery. By means of longer trips and fewer days spent in port, the fishing time was increased until it more than compensated for the decreasing abundance, so that the catch per trawler continued to rise. In addition, the total catch was considerably augmented by the increase in the size of the fleet through the construction of new craft. As a result, the total landings continued to increase until 1929, although the catch per day's fishing began to drop during the last part of 1927. By 1930 the level of abundance had fallen to a point where the total catch could no longer be maintained, in spite of increased fishing effort, and there was consequently a decided decrease in total landings in 1930 which continued in 1931.

By combining with the statistical analysis a study of the biology of the haddock stock, primarily size and age composition, growth rate and distribution, the causes of this change in abundance as reflected in the catch per unit of fishing effort are gradually becoming clear. It now appears that between 1920 and 1922 one or more extraordinarily successful haddock year classes were produced. In 1924 the largest of these fish had grown large enough to increase the catch of scrod haddock. In 1925 the full effect of this group was reflected in scrod landings, which were the greatest of any year since 1924, when our detailed records began. In addition, the larger members of this class were then of a sufficient size to be included in the category of "large haddock." In 1926 and 1927 as the full numbers of this enormous group came within the category of "large haddock" and as their total weight increased through growth, the abundance of haddock on the banks, as measured by the number of pounds caught per day's fishing, increased rapidly until a peak was reached in 1927. Since 1927 the catch statistics do not indicate the production of any year class at all comparable in numbers to those of the earlier period. In fact, since 1925 the catch of scrod has become successively less, in 1930 reaching the lowest point on record. Following this, in the latter part of 1931 there was a

marked increase in the scrod catch, the cause of which will be discussed later.

The increasingly intensive fishery for "large haddock," combined with the nonappearance of any year class of juveniles comparable to those of 1920–1922 to recruit the ranks, resulted in a rapid decline in the stock of fish which was necessarily reflected in the catch. The staggering nature of this decline is illustrated by records of one large group of trawlers. The average catch per trawler per day's fishing of this group on all banks decreased from about 19,000 pounds in 1927 to about 5,500 pounds in 1930.

It is obvious that there is no reason to expect an increase in the haddock population except through the appearance of numerous young from a successful spawning season, or through the immigration of large numbers from some great reserve stock not now known. The latter is a possibility frequently suggested by those connected with the fishery, but we have as yet obtained no data which in any way support it. Consequently, our hope for the immediate future must lie in the small haddock now present on the banks but still too small for commercial use. It is these fish which will determine the trend of the fishery during the next several years.

Work carried on during the past year, both at sea and on shore, has shown that there is now present on the banks a group of small haddock forming the most numerous year class which has appeared during the past several years. In the latter part of 1931 the largest individuals of this group were of sufficient size to be used as scrod, and their presence was reflected in the commercial catch by a remarkable increase in the scrod landings during the latter part of the year. By the summer of 1932 the main part of this class should be of scrod size and by the following summer the majority should qualify as "large haddock." But this will vary considerably on different banks according to the growth rate of the fish in different regions. On Browns and Western Banks this group appears to be present in considerable numbers; but due to a slower growth rate, the fish are of smaller size and consequently will not affect the commercial catch until later.

At present we are in no position to predict how far this influx of young haddock will go in restoring the fishery to the abundance of the past few years. Before such forecasts are possible it will be necessary to follow several groups through their life span in the commercial fishery to determine what effect a year class of a given abundance will have on the commercial catch over the period of years through which it is subject to the fishery. It seems safe to predict, however, from our present data, that the catch of scrod per day's fishing should continue at a high level during 1932, while there will be no permanent improvement in the catch of "large haddock" until the present scrod class reaches a sufficient size to qualify as such. On Georges Bank this should take place during the fall of 1932 and spring and summer of 1933, though some effect may be felt in the catch of "large" as early as the summer of 1932, especially in the Channel region.

It should be remembered, however, that the present fleet is larger than that which was operating when the 1920–1922 group was of scrod size. It is possible that the destructive effect of the larger

fleet may prevent the current group from attaining great importance, even if it was originally as numerous as the 1920–1922 broods.

Savings-gear work.—That there has been wholesale destruction of small fish by the gear now in use by the otter and V–D trawl fleet has long been known. Extensive records collected in 1915 and 1931 show that in those years from one-half to two-thirds of the haddock (in numbers) caught by these vessels were too small for commercial use. Similar damage was wrought among the young of other species. In the course of a year's time the aggregate number of small fish killed by this method of fishing was enormous.

A study of the problem was begun in 1931, when the haddock work began, and later tests were made of several types of experimental savings gear designed to permit the escape of fish too small for commercial use. The primary object of the experiments was to develop modifications of the commercial gear which would allow the escape of undersized fish without introducing complications that would make the gear unacceptable to the fishermen.

Except for some preliminary work at Woods Hole and on the *Albatross II*, the field work has been performed on board commercial vessels. This has made it very desirable to use a method of testing the experimental gear which would interfere with the fishing operations as little as possible. The trouser trawl was found to fit these requirements and gave very satisfactory results. The trouser trawl used consisted of a commercial otter trawl divided up the middle by a partition and with two cod-ends. The gear to be tested was placed on one leg of the trawl and the standard gear on the other.

The trouser trawl was used for preliminary tests to determine the size and mesh and type of construction necessary to permit the escape of undersized fish with no loss of marketable ones. These results were then utilized in the construction of a commercial savings cod-end. Considerable difficulty was encountered in making this gear sufficiently rugged to compare in durability with the present commercial gear on the rough bottom now being fished. A cod-end is being tested which has so far given satisfactory results. The general design is as follows:

The bottom of the cod-end is made of the same netting used in the present commercial gear. For the large boats this usually is 4-thread No. 900 manila twine doubled. The mesh measures 3–3½ inches between knot centers, stretched mesh. The taper on the top of the cod-end and 3 inches of the netting on the lower end of the top is of the same mesh as the bottom. The piece between the taper and lower end section is of 4-thread No. 750 manila twine doubled and 5-inch stretched mesh, and is knitted onto the small mesh at the upper and lower ends, taking up two small to one large mesh. The piece of large mesh is made about 20 per cent longer than the corresponding section on the bottom of the cod-end. This gives approximately the same area of netting on top and bottom and helps to keep the large top mesh open when there is anything in the cod-end. The small-meshed piece at the lower end of the cod-end top also gives additional strength to this section, where the chief strain comes in swinging the catch inboard; and if one strand is cut, no appreciable amount of the catch is lost.

On one trip to Western Bank a commercial trawl with this type of cod-end was fished alternately with a similar trawl using a commercial cod-end. It was found that with an equal catch of large haddock but one-fifth as many undersized ones were taken. The numbers of undersized fish of other species were reduced in proportion. Tests of this type of cod-end are being continued, and several improvements are being developed.

The gear experiments conducted by the bureau have been greatly facilitated through the cooperation of a number of commercial concerns. The Linen Thread Co., of Boston, Mass., and the Plymouth Cordage Co., of Plymouth, Mass., furnished much of the material and made up most of the experimental gear. Lloyd Runkle, of the former company, assisted on several field trips and had charge of constructing the experimental gear. Later in the work several commercial models were constructed by the Portland Trawling Co. in their net loft at Groton, Conn. Except for some preliminary work on the *Albatross II*, the field trials were conducted on the schooner *Exeter* and steamer *Kingfisher* through the generous cooperation of the General Sea Foods Corporation and Portland Trawling Co.

Early-life history.—Material has been collected during the past year concerning the location and extent of spawning areas and the movements of the eggs and larvæ during the period when they drift passively with the current. This material is used for the study of the interdependence of the various banks for their replacement of small haddock, and the causes of success or failure in the production of the different year classes.

During the haddock-spawning season in the spring of 1931 three trips were made on the *Albatross II*, each of about two weeks' duration, and covering a grid of 40 stations, spaced at 32-mile intervals each way, extending over the area from west of Nantucket Shoals to Browns Bank. At each station from one to four tow-net hauls were made, depending on the depth, using 1-meter silk nets and a Welsh trawl. The sorting and analysis of the collections have not progressed far enough to report results.

Hydrographic data, such as water samples and temperatures, were obtained at each station for the various depths, and on the last two trips 800 drift bottles were released, 10 to each station on each trip. The drift bottles were colored a brilliant yellow, a color which tests had shown to be most conspicuous under the conditions encountered. The returns from this work have been exceptionally numerous and have given us a much better conception of the surface currents in the Georges Bank region.

MACKEREL

The mackerel is prominent among the important food fishes of the Atlantic coast, not only for the magnitude of the annual catch, which in recent years has averaged around 40,000,000 pounds annually, but also for the extreme fluctuations in abundance which have characterized this species ever since records on this fishery were first kept, early in the nineteenth century. The objective of the bureau's investigations of this species is to ascertain the nature and causes of these changes in abundance, to determine whether they may be affected by man's inroads on the stock in the sea, or whether

they are due to natural causes beyond his control of such nature that they may be foreseen and turned to advantage by appropriate adjustments in the fishery.

The work to date has shown that the changes in abundance have been due primarily to the variable number of mackerel added to the stock by each year's spawning. This probably is because conditions for survival of the very young are much better in some years than in others, so that sometimes many mackerel grow to commercial size, while in other years very few survive the first weeks or months of existence. In years of good survival so many mackerel are added to the stock that a period of plenty ensues; and, conversely, during a series of years when survival is poor, so few are added that a period of scarcity follows.

This working knowledge of the mechanism of fluctuations has been attained gradually through seven years of close observations on the volume and age composition of the market landings of mackerel and from periodic surveys of the spawning and nursery grounds of the species by the bureau's fishery research vessel *Albatross II.*

The investigations were continued during 1931 under the direction of Oscar E. Sette. The data on market landings were collected mainly at New York during May and June, at Boston from June to October, and at Gloucester during November and December. These were augmented by observations at Cape May during April, at Newport during May and June, at Woods Hole from May to October, and during the summer at various minor ports in the Middle Atlantic region.

During the year the fleet landed 3,056 fares of mackerel, aggregating 36,490,847 pounds. By interviewing the masters of fishing vessels the date, locality, and quantity caught were ascertained for 1,329 fares, and samples of mackerel were measured from 856 fares. These, together with 10,883 mackerel measured from the pound net fishery, made a total of 35,068 measurements for the season. Scale samples were taken from 1,280 mackerel. Many mackerel-vessel captains continued to cooperate by keeping detailed logs of their activities. Thanks to the kindness of the Atlantic Biological Station, St. Andrews, New Brunswick, Canada, 26 samples, affording 2,623 measurements of gill-net and trap mackerel, were collected at Pennant, Nova Scotia.

The 1931 work has supplemented our previous understanding of mackerel fluctuations in numerous respects, but perhaps the most striking evidence of the approach to thorough knowledge is the gratifying outcome of the forecast on probable abundance during 1931.[2] Before discussing this subject in detail, it should be explained that the fishery draws mainly on the mackerel that are 2 years of age or older. Mackerel younger than this weigh less than a pound, are delicate, spoil readily, and can not compete in the open market with the larger and more desirable mackerel. They usually are sold in a separate category known to the trade as blinks and tinkers. Because of the peculiar combination of economic and biological conditions that

[2] Outlook for the mackerel fishery in 1931. By Oscar E. Sette, Bureau of Fisheries, Fishery Circular No. 4, August, 1931 (approved for publication May 26, 1931).

influence the catch of these small mackerel, and because of the difficulties of getting a measure of abundance of young mackerel before they are large enough to be caught commercially, the forecast was limited to the sizes larger than blinks or tinkers. In the forecast it was estimated that the abundance of mackerel would be such as to produce a catch of 35,000,000 pounds exclusive of yearlings (provided the fishing was approximately as intensive as in the previous year). Actually, the 1931 catch slightly exceeded 32,000,000 pounds, exclusive of yearlings. Thus the forecast was within 7 per cent of the realization. There has not yet been opportunity to analyze the statistics, but we are under the impression that the fleet was approximately the same size and as active as in the previous year. When it is recalled that the catch of mackerel is sometimes subject to fluctuations of the order of 50 or 100 per cent, the closeness of the prediction may be appreciated.

The satisfactory outcome of the 1931 prediction must not be received as an indication that forecasting is established on a sound basis; on the contrary, there are elements in the behavior of various contingents of mackerel which may easily prove disconcerting in future predictions. For instance, the 1928 class of mackerel appears to have had a much higher loss rate than the 1923 class at a similar age. It remains to be determined whether this was due, in fact, to a difference in death rate or to an artifact traceable to a more intensive fishery at one time than the other. There is also the additional possibility that neither was the case, for the same effect might be produced by an intrinsic difference in the habits of the 2-year classes which might render them susceptible to larger catches at one stage of their life history than at another. A notable difference in the areas frequented by these year classes strongly hints at this possibility. Continued observations and more intensive analysis of the data are in order.

An equally serious weakness in the observations from the standpoint of forecasting methods is the inability to get a measure of abundance before a year class is first old enough to be an important component of the commercial catch. This difficulty may be overcome by discovering the cause of variations in the size of the year classes so as to estimate the abundance independently of the commercial fishery, and in advance of the earliest exploitation. To this end the fisheries-research steamer, *Albatross II*, has periodically cruised the spawning and nursery areas of the mackerel in order to collect data as to the abundance of the eggs and young stages, and as to the physical, chemical, and biological conditions in the environment which might have an influence on the number surviving the hazards of their early existence. While it is yet too early for conclusive results, differences in the abundance of late larval stages have been discovered that may prove useful to indicate the numerical strength of the year classes. Particularly noteworthy was the widespread presence of late larvæ in 1931, the significance of which will be established when these mackerel become of commercial size in 1932 and 1933.

The work on the spawning grounds should not only aid in arriving at more reliable forecasts but should also provide information as to the conditions that control the production of successful year

classes. This is a question of fundamental importance in fisheries science, and its answer would be of inestimable value to the solution of fishery problems.

To provide data for the interpretation of findings on the mackerel-spawning grounds, with special reference to the influence of ocean drifts in transporting fish eggs and larvæ, experiments on the rate of development of mackerel eggs were carried out by Leonard G. Worley during the spring of 1931. He found that the eggs of this species hatched in 6½ days at 11° C. and 2 days at 21° C., with corresponding incubation periods for intermediate temperatures. In addition, it was found that the limits of successful hatching were between 10° C. and 22° C., with the maximum percentage hatching at 16° C.

COD

Studies of the migratory habits and other phases in the life history of the cod were continued by William C. Schroeder during 1931, though field work was limited by the requirement of personnel and vessels on other projects. Marking experiments were made in the following localities: (*a*) Woods Hole, Mass., January 8–9; (*b*) Nantucket Shoals, August 10–11; and (*c*) Mount Desert, Me., June 21–29.

The results in general resembled those of the preceding years, corroborating earlier conclusions that many of the cod which summer off southern Massachusetts migrate westward in the fall to winter off Rhode Island and the Middle Atlantic States region, but that the shore cod of eastern Maine remain for the most part localized, a few of them moving north and east to Nova Scotia.

A total of 45,452 cod was tagged at sea from 1923 to 1931, of which 3,204, or about 7 per cent, were reported recaptured, the returns from some lots of fish being as low as 1 per cent, while from others they have been as high as 35 per cent. In addition, 2,223 cod were tagged and liberated at the Woods Hole fisheries station from 1926 to 1931, of which about 3¼ per cent were reported recaptured.

A new type of tag made of two small, thin celluloid disks, resembling the Scottish plaice label, was devised by R. A. Nesbit in connection with his study of tagging methods useful for Middle Atlantic fishes. This celluloid tag was used for tagging cod during 1930 in place of the metal-strap tag employed in previous experiments; and although but little more than a year has elapsed, it gives promise of being much more efficient than the old one. For example: Whereas only about 3 per cent of the Monel-metal tags were recovered the first year from cod tagged on Nantucket Shoals during 1923–1929, the returns from the celluloid tags used in that locality in October, 1930, amount to 15 per cent for the succeeding 12-month period. While these favorable returns demonstrate the superiority of the new style tags during the first year of release, it still remains to be seen whether they persist during later years.

The results so far obtained from this new disk tag make it desirable to continue cod-marking experiments on the prolific offshore grounds, from which only meager data have been obtained; chiefly, perhaps, because of the inefficiency of the metal-strap tag. An important objective is determination of the sources of replenishment for the

stocks of commercial-sized cod on the offshore banks—especially whether these grounds are self-supporting or whether they depend in a large measure on immigration of juveniles and adults from other grounds. The continued marking of 1, 2, and 3 year old fish in the shore waters along the coast of Maine, an important nursery for young cod, is expected to throw some light on this question. In past experiments in this region the marked fish have been rapidly caught up by local fishermen and the tags were seldom carried by the fish for more than a year. However, by marking in localities not ordinarily visited by fishermen and by using improved types of tags it is hoped to trace the migration of these young fish when they become older and move offshore.

WINTER FLOUNDER

As mentioned in the previous annual report, such concern has been felt over the welfare of the flounder fishery that certain waters have been closed by State law to flounder draggers during a portion of the season. A comprehensive investigation is therefore urgently needed to determine whether in fact this species is being overfished; and, if so, what practical methods of conservation should be adopted. Though the means for such an investigation have not been available to the bureau, a limited program was begun in 1931 that throws some light on the pertinent question of whether the winter flounder *Pseudopleuronectes americanus*, migrates widely from place to place or whether the various grounds have separate, self-perpetuating populations. In the one case overfishing at any one place would reduce the population at other places also. In the other case the effects of overfishing would be felt only in the locality in which it occurred. Obviously, this information is a preliminary necessity for an understanding of the ability of the species to support the commercial fishery and for designing protective measures if such be needed.

In Waquoit Bay, near the United States Fisheries Biological Station, Woods Hole, Mass., a concentration of winter flounders regularly occurs, many of which are spawning fish. Mixed with the spawners are juveniles, immatures, and spent individuals. During the period from February 13 to April 3, 1931, 4,179 flounders, both young and old, were tagged and released. The work was done by Robert A. Goffin and Henry M. Bearse under Robert A. Nesbit's supervision. The tag used was similar to the Scottish plaice label, consisting of two celluloid disks held together by nickel wire passed through their centers. About half of the flounders were tagged just below the dorsal fin immediately posterior to the head; the remainder at a similar point midway between snout and tail.

Returns to December 31, 1931, totaled 84 fish, exclusive of 56 which were taken by the hatchery's fishing crew within 40 days of the time of tagging and again released. These recaptures show that there is a definite movement of flounders in spring toward offshore waters, mostly eastward through Nantucket Sound, but with a few straying westward through Buzzards Bay or Vineyard Sound. By summer time tagged fish were recaptured for the most part in the open waters

both north and south of the mouth of Nantucket Sound. A few returns were from the shores of Long Island, some 150 miles to the westward of the tagging locality. In the autumn returns were reported from the sounds, and by December several were recaptured in Waquoit Bay, where they had been caught and tagged nearly a year previously.

SHORE FISHES OF THE MIDDLE ATLANTIC STATES

Investigation of the causes of fluctuations in yield of the shore fishes of the Middle Atlantic States, begun in 1927, was continued under the direction of R. A. Nesbit. Field bases were maintained during part or all of the 1931 fishing season at Woods Hole, Mass.; Newport, R. I.; Montauk and Fire Island, N. Y.; and Belford, Long Branch, Deal, Seaside Park, Beach Haven, and Wildwood, N. J. At these bases the principal data obtained were detailed records of the catch, with length-frequency observations of the principal species occurring in the region (squeteague, scup, butterfish, sea bass, and summer flounders) and the collection of squeteague scales.

Squeteague.—Especial attention has been paid to analysis of the data pertaining to squeteague, this being the most important species of the region, the yield of which in New York has recently been so low as to cause concern. Procedure in 1931 was directed toward determining whether the stock of squeteague north of Delaware is self-perpetuating or whether it is maintained by migration of fish from southern waters. One thousand four hundred and ninety-three squeteague, mostly yearlings, were tagged by W. C. Schroeder in Chesapeake Bay during October, 1931, with the expectation that should any general northern migration of these yearlings occur in 1932, they should be recaptured in the New Jersey and New York region. A second line of procedure consisted of careful studies of the scales to determine whether squeteague from different localities show significantly different rates of growth. Remarkable differences between the growth increment of the third and subsequent summers were noted in fish from different localities. Thus, the average third summer increment for squeteague at Montauk, N. Y., was three times that at Wildwood, N. J. Calculated increments for the first and second summers for fish taken in New York and New Jersey in their third and subsequent summers are in good agreement with the corresponding increments observed in Virginia fish. These observations indicate that northern stocks of adult squeteague are in part at least recruited from southern nursery grounds, but final judgment will depend on the results of tagging experiments.

The scale studies on which the calculations of growth rates were based have cast much light on the forming of the annulus or year mark. It was noted by Taylor that the annuli in the squeteague scale became apparent in July. Our observations have shown that the first annulus usually appears before the fish becomes sexually mature; hence it seems unlikely that the check is caused by the effort of spawning. Comparison of scale length with age length by months indicates that the scale ceases to grow about the first of October, although the body continues to do so. Scale growth is not resumed until the following July. As the annulus can not be seen until new

growth has begun, an annulus which really was formed in October appears to be formed in July. When the scale resumes growth it does not regain the ground lost during its period of inactivity. Consequently, the average scale length of old fish is less than that of younger fish of the same size.

Reexamination of published observations on rate of growth of herring and young cod scales relative to that of the body discloses a similar situation, with the important exception that in these species the summer growth more than compensates for the period of winter inactivity, so that the net result is a gain in scale length relative to that of the body. These facts undoubtedly are an important factor in causing the distortions which have resulted from attempts to calculate growth increments from scales.

Scup.—The yield of scup has been subject to wide fluctuations during the past 40 years both in New York and in New Jersey. The record since 1921, covering the period of a significant increase in yield from pound nets, is more complete for New Jersey than for New York. Hence the present discussion will be limited to consideration of fluctuations in New Jersey and their causes.

The pound-net yield, as indicated by periodic canvasses, shows low levels of abundance during the period from 1890 to 1908, followed by increases in 1917 and 1921. In 1926, however, the catches again declined to a level only slightly higher than that of 1908. In 1929 a notable increase occurred, the total pound-net catch for New Jersey rising to the highest figure since 1921. This level was well maintained in 1930 and 1931.

Compilation and study by W. C. Neville of the data on lengths of scup collected from commercial catches from 1928 to 1931 show that the sudden increase in the scup catch during 1929 was due to the influx of an abundant brood produced in 1927, which first reached commercial size in 1929. In 1928 this group was heavily represented in the catches sampled, but as the fish were below legal size they had no effect on the reported yield.

When they reappeared in large numbers in 1929 they were salable, and raised the reported yield to record figures. But continuation of high pound-net yields in 1930 and 1931 was due only in part to the continued presence of the 1927 brood, for the 1928 brood was also large and served to offset the diminution in the numbers of 1927 fish returning in these years.

It is to be noted that both the 1927 and 1928 broods were produced in years in which the pound-net yield was at a low ebb. If the pound-net yield constitutes a reliable index of actual abundance of scup, it might be inferred that even a greatly reduced stock is capable of producing sufficient numbers of eggs to restore high levels of abundance, provided conditions for development are favorable.

That this is not necessarily the case is indicated by data from the offshore fishery during the past few years. In 1928 otter trawlers, purse seiners, and offshore pounds located on Five Fathom Bank took fair numbers of larger and older scup than those which made up the scanty inshore pound-net catch of that year. In 1929, when large catches of scup of the 1927 brood were made inshore, the offshore fishing took few of these, depending, as in 1928, on a stock of older and larger fish than those found inshore. In 1930, and to a greater

extent in 1931, the 1927 brood began to affect the offshore yield, coincident with lessened importance in the inshore catch.

It thus appears that on reaching commercial size, scup first are taken by the inshore pounds. As they become older and larger they are no longer available to this gear, but are taken by the offshore fishery.

In view of the complete recovery of the fishery in 1929 and subsequent maintenance of satisfactory yields it is apparent that the scup is not in need of protection from the fishery as carried on prior to 1929, for the offshore fishery was of such small proportions that it took only a small toll from the spawning reserve of large adults which escaped the pound net fishery.

Since 1929, however, two important changes in the fishery necessitate careful reexamination of the capacity of the scup to withstand the strain imposed. The first is a rapid expansion of the offshore otter-trawl fishery during the summer, and the second the rapid growth of a winter-trawl fishery (2,000,000 pounds were landed in 1930–31). Although this fishery is conducted in southern waters, there is a possibility that it takes toll of a stock drawn from the summer population of the whole Middle Atlantic region.

The increased summer-trawl fishery and possibly the winter fishery have increased the toll taken from the stock of older fish previously protected from man and available as a spawning reserve. Just what the minimum size of the scup population need be in order to maintain an adequate spawning reserve is an open question. Although it has been shown that the 1927 and 1928 broods were the result of a spawning population that certainly was not taken in large commercial quantities by the inshore pound nets in these years, there still remains the probability that these broods may have resulted from the spawning activity of the larger offshore fish, the existence of which was not realized prior to the growth of the offshore-trawl fishery.

Thus the principal threat to the welfare of this fishery is the possibility that the spawning reserve may be reduced beyond safe limits. In order to determine whether this is the case it is planned to:

(1) Observe rate of decline of important broods as shown by catch records and continued length data.

(2) Estimate the fishing strain from recapture of scup tagged at appropriate points. The tagging program will also serve to indicate the extent to which the winter fishery imposes an additional strain on the scup population of the Middle Atlantic States. This project was begun in 1931 by the tagging of 1,000 scup at Woods Hole, and 1,500 at a number of points between Cape May, N. J., and Cape Charles, Va. Additional tagging will be done off the Virginia coast during the winter of 1931–32.

Utilization of any surplus in excess of spawning needs is desirable, otherwise the more valuable commercial sizes would be wasted; but pending the outcome of the investigation described above, no restriction of the fishery is recommended.

Butterfish.—In the early years of the Middle Atlantic fisheries the butterfish, like the whiting to-day, was incompletely utilized. At present, however, the demand is ordinarily sufficient to insure profitable sale of all that are taken. It has become one of the mainstays

of the pound-net fishery. In view of its present importance it is desirable to determine whether it is in need of protection to insure continuation of satisfactory yields.

Analysis by H. M. Bearse of length-frequency data for three years, coupled with the results obtained from study of the catch records, has shown that the abundance of butterfish is definitely related to variations in success of reproduction from year to year. The New Jersey State records and the individual pound-net company records show an unusually good catch per unit of gear for the year 1929. The length frequencies for the year 1928 demonstrate the presence of a group of small and medium fish dominating the catches at most points along the coast; those for 1929, a group of medium and large fish appearing in overwhelming numbers; and those of 1930, dominated by large fish. From the consistent behavior of the size variations for the three years it is clear that the catches during that period have been made up largely of fish resulting from a single spawning, presumably that of 1926.

The effect of this large brood was to increase the total catch of butterfish as well as the catch per unit of gear for the season of 1929 in New Jersey. Although a large proportion of the fish taken by pound nets in 1928 and 1930 was of the same brood as those taken in 1929, the yields for these years were moderate. In 1928, however, these fish were for the most part too small to be salable, and the majority of those taken did not enter into the recorded catch. The decline in 1930 probably was due either to natural mortality and to the fishing, or to a change in habits with age similar to that described for the scup. No evidence on this point is available, as few butterfish are taken by gear other than pound nets.

It appears, therefore, that the restoration to nearly record levels in 1929 without protection demonstrates the ability of the butterfish to withstand the strain of the fishery, unless unforeseen developments should increase the exploitation of this species.

Early-life histories.—Studies of spawning and nursery grounds of Middle Atlantic fishes were continued under the able direction of Prof. A. E. Parr, curator of the Bingham Oceanographic Foundation, Yale University. The work which began in Delaware Bay in 1929 was continued in 1931 and extended to Barnegat Bay and Sandy Hook Bay. Many data bearing on the abundance and rate of growth of young squeteague, scup, spot, and sea bass were collected.

Of special interest is the observation that the presence of even very small juveniles in a locality does not necessarily imply successful local reproduction. This is illustrated by two species—the mullet, *Mugil cephalus*, and the spot, *Leiostomus xanthurus*. The former species does not spawn in New Jersey; in fact, it is doubtful whether the adults occur there at any time; yet juveniles are common. Juveniles of the spot, less than an inch in length, appear along the shores of New Jersey and New York. Since this species spawns in winter when neither adults nor larvæ occur north of the mouth of Chesapeake Bay, these juveniles can not have resulted from local spawning; but they must have migrated from localities well to the south, perhaps in part from North Carolina waters. While they are in

New Jersey, young spot grow more rapidly than those which remain in the South.

The interdependence of northern and southern stocks of spot is further evidenced by facts pointing toward a southward migration of young spot in the autumn, for their disappearance at that season from New Jersey waters is accompanied by a sudden increase in average length of the stock of spot in North Carolina, due doubtless to the addition of the faster-growing northern spot to the North Carolina population. This view is supported by the winter recapture in North Carolina of a young spot which had been tagged in New Jersey the previous October.

As in 1929 and 1930, large collections of squeteague eggs were made in June, 1931, near the mouth of Delaware Bay, but no larvæ were taken. Although numerous juveniles were taken subsequently, they appeared too late to have resulted from the spawning noted. It remains an open question whether these juveniles resulted from local spawning which escaped observation or whether they, like the spot, migrated while still very small from the southern grounds where larvæ as well as eggs have been captured.

OCEANOGRAPHIC STUDIES

As more and more of the fluctuations of our fisheries are traced to variations from year to year in the survival of the early stages of various species, the discovery of the causes of this variation becomes more and more urgent. This involves a greater understanding of oceanographical conditions than has yet been attained. Although the bureau does not have the means to enter into this field at present, it has been fortunate in having the study of the physical oceanography and the plankton of the waters overlying the continental shelf between Cape Cod and Cape Hatteras undertaken by Dr. Henry B. Bigelow, director of the Woods Hole Oceanographic Institution, and Mary Sears.

Much of the material necessary for this study has been accumulated on cruises made by the *Albatross II* in that area for investigation of the spawning of the mackerel. Additional data and collections are being secured by the research ship *Atlantis* of the Woods Hole Oceanographic Institution to supplement collections already made.

A résumé of oceanographic work done by the *Albatross II* during 1931 appears in the accompanying table.

TABLE 1.—*Summary of offshore oceanographical work done in conjunction with cod, haddock, mackerel, and shore-fish investigations, 1931*

Date	Station numbers [1]	General locality	Number of stations occupied	Temperature and salinity observations	Collections made			
				Serials, surface to bottom	Phytoplankton surface horizontal	Zooplankton oblique	Welsh trawl	Otter trawl
Feb. 13-14	20877-20883	Massachusetts Bay and Georges Bank.	7	7	6	11		
Feb. 17-Mar. 5	20884-20922	No Mans Land, Mass. to Ocracoke Inlet, N. C.	39	39	7	[2] 37		[3] 27
Mar. 19-31	20923-20963	Georges Bank and Nantucket Shoals	41	41	41	84	3	
Apr. 16-29	20964-21003	do	40	40	39	83	8	[3] 8
May 16-22	21004-21038	No Mans Land, Mass. to Assateague, Va.	35	35	35	66	11	
May 26-June 9	21039-21075	Georges Bank and Nantucket Shoals	37	37	37	80	22	
June 12-19	21076-21116	Cape Cod Bay to Chesapeake Bay.	41	41	41	89	21	
July 7-16	21117-21152	Cape Cod Bay to Barnegat, N. J.	36	36	36	79	30	
July 24-28	21153-21180	Gulf of Maine	28	1		3		[4] 28
Aug. 9-11	21181-21195	Nantucket Shoals	15	15				[4] 1
Aug. 27	21196-21199	Offing of Chatham, Mass.	4	4	4	13	4	
Aug. 31-Sept. 9	21200-21233	Montauk Point, N. Y. to Browns Bank.	34	[5] 34				[3] 39
		Total	357	330	244	545	99	103

[1] Albatross series.
[2] Includes 9 horizontal zooplankton hauls at the surface.
[3] 60-foot otter trawl.
[4] 35-foot otter trawl.
[5] Temperatures only.

EXPERIMENTAL REARING OF FISH LARVÆ

As discussed in previous sections, many of the fluctuations in yield of our food fishes are due to variations in the success of various year classes pointing to critical stages in the early life history of the species. Studies on oceanic conditions may reveal the causes for excessive mortality in some years and nominal losses in others; but the probability of ascertaining them might be enhanced greatly if it were known what conditions of temperature, salinity, light, and other physical and chemical properties are favorable to survival of the newly hatched young of fishes, and what food materials must be provided.

Generally speaking, it has been impossible to rear the newly hatched young of marine species of fish under laboratory conditions. However, in the summer of 1929 and 1930 Louella E. Cable succeeded in rearing several fish through the larval stages in the Beaufort (N. C.) laboratory and in 1931 conducted experiments at the

Woods Hole (Mass.) station. While the larvæ were not carried through the entire critical period, the work was successful in prolonging life somewhat beyond the normal period experienced by larvæ under the artificial conditions necessary in the laboratory, and there were revealed encouraging leads for future experimentation.

CHESAPEAKE BAY INVESTIGATIONS

After completing certain phases of investigations in the Chesapeake Bay region, a long-needed study of the life history of the striped bass, *Roccus lineatus*, in Maryland and Virginia waters was undertaken by John C. Pearson.

A study of the seasonal distribution and abundance of pelagic marine fish eggs and young fishes at the entrance to Chesapeake Bay was completed and a report submitted for publication. Besides showing the seasonal occurrence of at least 40 species of pelagic young marine fish and the location of the spawning grounds of the squeteague or gray sea trout in the Chesapeake Bay region, the investigation added to our knowledge of the life histories of many valuable food fishes, such as the gray sea trout, butterfish, harvest fish, and bluefish.

An investigation of the winter-trawl fishery off the Virginia and North Carolina coast during the winter of 1930–31 disclosed the rise of an important fishery in the South. The total yield of this fishery for the season approximated 5,600,000 pounds, valued at more than $600,000 to the fishermen. Nearly 50 trawlers engaged in the fishery, about half of this number coming from New Jersey, Massachusetts, and other northern fishing ports. Scup, croakers, summer flounders, sea bass, hake, and gray sea trout composed the bulk of the catch, although nearly all of the principal food fishes of the North, Middle, and South Atlantic States were represented. This fishery has furnished material for a paper entitled “The winter-trawl fishery off the Virginia and North Carolina coasts.”

In the spring of 1931 a study was commenced to ascertain the major features of the life history of the striped bass in Chesapeake Bay. The striped bass supports one of the most valuable of Maryland’s marine and fresh-water fisheries, ranking as the third most valuable food fish in price per pound in the United States. The striped bass is not only one of the leading food fishes, but it has become a leading sport fish both on the Atlantic and Pacific coasts.

The investigation of the species in Chesapeake Bay during the first year has consisted largely of migration studies. Interesting and significant results from tagging experiments are indicated. Spawning areas, rate of growth, and conservation requirements of the species will be studied during the coming year.

SOUTH ATLANTIC AND GULF FISHERIES INVESTIGATIONS

The investigations of fishery problems in the South Atlantic and Gulf States include studies of the shrimp fisheries from North Carolina to Texas, studies in oyster culture in the States of North Carolina, South Carolina, Georgia, and Florida, and ichthyological studies of the fish fauna of the Gulf coast. In addition to

these, various activities at the Fisheries Biological Station, Beaufort, N. C., have general application to the fisheries of that region. Inasmuch as this laboratory is in operation throughout the year, the investigations conducted there during 1931 are discussed in a later section.

Red-snapper investigation.—In response to a request to investigate an alleged shortage of red snappers in the Gulf of Mexico and to offer suggestions for increasing the catch of fish in that region, William C. Schroeder was detailed to Pensacola from October 13 to November 2. Since the work was limited to several weeks' investigation of the Gulf's snapper fisheries, it could not be determined whether the stock of fish had suffered depletion, but it was evident that the present low yield might be materially increased by greater expenditure of effort on the part of the fishermen. Trawl-line gear such as is used off the New England coast was tried with some measure of success by using floats to keep it clear of coral, and it appears probable that Gulf of Mexico fishermen could make use of this gear in addition to hand lining, which at present is the only method used for catching ground fish in that region. It is desirable also that soundings be made in the Gulf, especially between about 30 and 120 fathoms and within about 150 miles of Pensacola, to learn whether any new fishing grounds exist within convenient distance of the local fleet.

SHRIMP

Since 1880 the production of shrimp has been increasing at a uniform rate, doubling itself about every 8½ years, until in 1930 canned shrimp ranked as the fourth most valuable fishery product in the United States, including Alaska. This rapid increase in the fishery caused great anxiety for the future of the industry and resulted in many requests for a complete study of the problem. With the increased funds made available after the passage of the 5-year program bill, the Bureau of Fisheries was enabled to undertake an extensive investigation of the abundance and life history of the shrimp. As recorded in the report of last year, Dr. F. W. Weymouth, professor of physiology of Stanford University, Calif., was chosen to supervise the investigation.

In February, 1931, the chief of the division of inquiry, accompanied by Doctor Weymouth and Milton J. Lindner, formerly with the State Fisheries Laboratory of California, visited the chief shrimp ports for a brief survey of the state of the fishery.

The initial step of the investigators was to arrange the details of cooperation which had been offered by the various States in which shrimping is prosecuted. As this fishery extends over more than 3,000 miles of coast line, it was deemed necessary to cooperate with as many States as possible in order to obtain the most complete information with the limited funds available. Through the foresight of Commissioner Peter S. Twitty, Georgia had inaugurated investigations early in September, 1930, at Brunswick, Ga., to observe the fishery.

Louisiana, the center of the shrimp industry, offered to join the Bureau of Fisheries in a joint program. Commissioner Robert S. Maestri appointed J. N. Gowanloch to head the staff of the newly

created bureau of research and statistics to cooperate in this investigation. Through the courtesy of the department of conservation, offices for the joint staff were obtained in New Orleans, and a boat furnished by the bureau was refitted by the State and placed at the disposal of the investigators. Later Texas, through William J. Tucker, executive secretary of the game, fish, and oyster commission, expressed a desire to cooperate in the investigation. An investigator was employed and stationed at Aransas Pass, Tex., to conduct observations on the commercial catch.

International cooperation has been effected by the action of Dr. R. von Ihering of the Instituto Biologico of Sao Paulo, Brazil. In this country the shrimp fishery is of considerable importance, and Dr. von Ihering has kindly furnished statistics of the catch and valuable specimens from various localities, thus extending the scope of the inquiry far to the south and covering practically the entire range of the species.

The combined staffs, in consultation with the bureau's officials, carefully considered the problems presented by the shrimp industry, with the objectives of (1) maintaining the optimum productivity of the fishery and (2) furnishing biological information useful to fishermen, packers, and legislators. The program so formulated comprises the following fields of investigation:

(*a*) Life histories of the principal commercial species, including problems concerning breeding, spawning, embryology and larval history, postlarval growth, and longevity.

(*b*) A statistical analysis of abundance which would require a compilation of the existing data and plans for the gathering of future statistics.

(*c*) Habits and reactions of the young and adult shrimp in relation to food and food getting, migrations, molting, spawning, temperature, and salinity.

(*d*) A systemic examination of all shrimp occurring in the commercial catch in the various fishing localities and biometrical studies of the principal species throughout their range for the determination of possible racial differences which would have a bearing on problems of migration or local depletion.

(*e*) The effects of fishing in relation to gear, localities, and time on the composition of the shrimp catch and on the other species of economic importance.

(*f*) The anatomy of the principal species of shrimp in relation to spawning and feeding.

(*g*) Diseases and parasites affecting the shrimp.

It was decided that the bureau's investigators should devote their efforts mainly to classes (*a*), (*b*), (*d*), and (*e*), and the scientists of the Louisiana Department of Conservation to direct their activities toward the solution of (*c*), (*f*), and (*g*), with general consultation and cooperation in all phases of the problem.

Of the species appearing in the commercial catch *Penæus setiferus* is by far the most important and deserves the most intensive study; only two others, *Penæus brasiliensis and Xiphopenæus kroyeri*, are abundant enough to require consideration.

Progress toward the various objectives outlined above is being made; but because of the complexity of the problem, it seems advis-

able to defer any formulation of results until more data are available. Because of their importance, however, the trend of work in two phases may be mentioned. A satisfactory analysis of the catch statistics, especially in regard to the intensity of fishing, a question of prime importance, is impossible because of the inadequacy of the data. It will be necessary to have recourse to figures supplied by certain packers who have records of catches of individual boats over a number of years. The inadequacy of the fisheries statistics in the States concerned is so serious a handicap to investigations of this character that it is hoped in the future some of the far-sighted legislators may be able to remedy this unfortunate lack.

With regard to the life history, the size-composition analysis of the catch, particularly in Georgia, is furnishing valuable information. Although it would be premature even to outline the life history, there can be little doubt that the life span is short and that most of the fishery rests upon dangerously young or spawning individuals. It can not be too strongly emphasized that under these circumstances depletion, when it appears, is sure to run a tragically rapid course and that every opportunity should be embraced to furnish reasonable protection to this valuable animal.

GREAT LAKES FISHERY INVESTIGATIONS

The major field investigations in the Great Lakes area during 1931 were conducted on Lakes Michigan and Huron, while minor field operations were carried on on Lake Erie and also on Lake Champlain. Only one new major project was started in 1931, viz, the investigation of deep trap nets on Lake Huron and upper Lake Michigan. The other field investigations were continuations from previous years, those on Lakes Erie and Champlain being completed in 1931. As in previous years, the bureau enjoyed the fullest confidence of the conservation departments of the various Great Lakes States and of the fishermen and worked in close harmony with them. In spite of the severe curtailment in their appropriations, the States of Michigan and Wisconsin again gave liberal financial support to the Lake Michigan program, while the State of Vermont gave generous financial assistance in the Lake Champlain work.

CHUB-NET STUDIES IN LAKE MICHIGAN

The Lake Michigan investigation on chub nets, started in 1930 (see report for 1930) and conducted jointly with the conservation departments of Michigan and Wisconsin and a group of four fish-net and twine companies located in the Great Lakes area, was resumed in 1931, since it was found that in spite of the large numbers of fish employed in our 1930 experiments they gave no conclusive results. The primary objective of the Lake Michigan work was a study of the catch of chub nets in order to determine the selectivity of these nets with regard to chubs and to determine their destructiveness to immature trout.

The bureau's vessel *Fulmar*, again employed for the work, left its winter quarters at Sturgeon Bay, Wis., on April 23 for the first cruise of the season after having been thoroughly overhauled and painted during the winter months. Field operations continued until November 19. During this period the *Fulmar* covered a total dis-

tance of some 8,280 miles. Regular fishing operations were carried on from 6 Wisconsin ports, 5 Michigan ports, and 1 Illinois port. The usual procedure was to fish nets simultaneously out of six ports and make occasional changes in the itinerary in order to cover new fishing grounds. Nets with stretched meshes of the following sizes were fished: 2⅜, 2½, 2⅝, 2¾, and 3 inches. Data were recorded on the total bulk weights and numbers of trout and chubs taken by the nets of each size mesh. Individual lengths, weights, sex, and sexual maturity were recorded for all trout, and stomachs were preserved from occasional samples for food studies. Chubs were sorted by species, and individual biological data obtained for each species to the extent that time permitted. A grand total of 1,654 chub nets, each 510 feet long, or, in terms of total length, 159.7 miles of nets, were lifted during the season. Of these nets 929 were fished and lifted in Wisconsin waters, 576 in Michigan waters, and 149 in Illinois waters.

During the 1931 season 87,018 chubs and 8,551 lake trout were taken, which weighed 28,517 and 6,633 pounds, respectively. The figures show that both trout and chubs are more abundant in the Michigan waters than in the waters of either Wisconsin or Illinois. It is possible that this difference in abundance may be attributed to the larger mesh employed for chubs in the State of Michigan. Throughout the season it was found necessary to fish more nets on the Wisconsin shore than on the Michigan shore in order to secure adequate catches for biological data.

In addition to the fishing of experimental chub nets, certain hydrographic data were collected whenever weather permitted. This work suffered greatly during 1931 because of an unusually windy season and, hence, more complete series of data could not be obtained. The following data were secured in different parts of the lake: Temperatures, plankton samples, bottom organisms, bottom soils for geological analysis, and occasional transparency readings. Sixty-four soil samples, 160 plankton samples, and 75 collections of bottom organisms were secured. Temperature series in the deeper portions of the lake showed many reading below 4° C., the temperature at which fresh water reaches its greatest density. Bottom temperatures in localities more than 150 meters deep usually showed a tendency to run slightly less than 4° C. The lowest temperature obtained during the season occurred in 220 meters, 32 miles W. ½ S. of Manistee, Mich., where a reading of 3.6° C. was obtained.

A study of the surface currents of Lake Michigan as determined by drift bottles was begun on June 17 and continued until August 17. Some 283 bottles were set adrift during these two months, usually in transverse series across the lake. The bottles of a series were released at intervals of approximately 2 miles. The southernmost series extended from Chicago to St. Joseph, Mich., and the northernmost from Frankfort, Mich., to Kewaunee, Wis. Of the 283 bottles set adrift, 180 have been recovered to date, or a percentage recovery of 63.6.

The majority of the drift bottles recovered showed a tendency to move northward, which was to be expected because of the prevalent southwesterly winds. It is planned to continue these studies during the summer of 1932.

DEEP TRAP NETS OF LAKES HURON AND MICHIGAN

A new cooperative investigation, separate from that on the chub net, was started with the States of Michigan and Wisconsin on the deep trap nets. In June, 1929, the deep trap net was introduced in Lake Huron at Port Hope, Mich., primarily for the purpose of taking whitefish. During the past two years this type of gear has spread very rapidly throughout Lake Huron and upper Lake Michigan, including Green Bay. A deep trap net is virtually a submerged pound net, since it has lead, a heart, a tunnel, and a pot or crib. The crib where the fish are finally captured is entirely inclosed so that the entire net can be completely submerged. The crib varies from 18 to 35 feet in depth, 30 to 40 feet in length, and in width usually tapers from 24 feet at the front to 20 feet at the back, and the lead varies in depth from 25 to 45 feet. This net is usually fished at depths varying from 60 to 125 feet, although it can be fished at greater depths.

The principal criticisms heard regarding deep trap nets are that they take too many adult whitefish, thereby depleting the stock in the lake and glutting the market, and that they destroy too many undersized fish. The States of Michigan and Wisconsin and the fishermen are deeply concerned about the rapid spread of these nets throughout the Great Lakes and have therefore urged the bureau to make a study of their action upon the fish stock. The patrol boats of the conservation departments of both States were placed at the bureau's disposal in the preliminary surveys.

The survey in Wisconsin waters was completed during the period July 6 to 16, 1931, and a report, including a set of recommendations, was submitted by the joint commission. The survey in Michigan waters was carried on from July 24 to October 21, 1931, out of the following ports: Bay Port, East Tawas, Oscoda, Ossineke, Alpena, Rogers City, Cheboygan, Epoufette, Naubinway, Manistique, and Fairport. The Conservation Department of Michigan furnished one assistant for this work and all transportation. In view of the great importance of the study and of the many complications involved, it has been deemed advisable to continue the investigation another year before drawing up final recommendations.

STUDIES IN LAKE ERIE

Fishery investigations.—The spring of 1931 saw the completion of our experimental fishing with trap nets on Lake Erie begun in the fall of 1927. The report for 1930 referred to the study of the fishing characteristics of one of our experimental trap nets. This particular study was carried on at Lorain, Ohio, in 1930 for various species of fish, excluding the sauger, a species relatively unimportant in the commercial catch at Lorain. Since the only remaining principal objection of the commercial fishermen to the introduction of our experimental trap net for commercial fishing on Lake Erie was that too many legal saugers would be released by it (it is asserted that the sauger is the most active of the Great Lakes commercial species of fish and would escape from a net which would retain other less active species), it was deemed desirable to resume the experi-

ments of 1930 at Sandusky, Ohio, on sauger grounds and during the sauger run in the spring of 1931.

Accordingly two investigators were detailed at Sandusky and carried on these experiments during the period March 12 to May 20, 1931. Length and weight measurements were secured for some 33,500 fish, including perch, saugers, and yellow and blue pike. It was found that though the percentage of legal fish released by our experimental net was greater in the case of the sauger than in the case of any other species studied, yet the benefits secured by the release of illegal fish would vastly compensate the fishermen for the loss of any legal fish. On the basis of our experiments we expect to recommend to the State of Ohio that the lifting crib of all trap nets be provided with a large mesh (not less than 3 inches as used) in the back and in one-third (or for a distance of not less than 3 feet) of the sides, top, and bottom adjacent to the back, and with a small mesh (not more than 2 inches as used) in the remaining two-thirds of the crib, including the tunnel.

In addition to the field work, much has been accomplished in the laboratory in a study of the life history of the yellow and blue pike perch, the sauger, the yellow perch, the whitefish, and the cisco of Lake Erie. The data for these studies were collected during our investigations of experimental fishing gear.

Limnological studies.—No field work was done in 1931 on the limnology of Lake Erie, but the time of one investigator was devoted entirely to the compilation of data collected over a period of five years and to the preparation of the final report. As stated in previous reports, the limnological investigation of western Lake Erie was carried on by the Ohio Division of Fish and Game, in cooperation with the bureau, under the immediate supervision of Dr. Stillman Wright. The principal objective was to determine the degree and extent of pollution and the effect of pollution on conditions of existence in the lake. The problem was attacked by making nearly simultaneous studies of the chemistry, plankton, and bottom organisms in the open lake, far from sources of pollution, and at the mouths of important rivers.

Conditions in the open lake were found to be apparently normal. The only evidence of pollution was the occasional presence of *B. coli.* At the mouths of the Maumee and Raisin Rivers there was considerable chemical evidence of pollution. However, the zones of oxygen depletion and carbon dioxide increase were limited to a small area in each case. Large amounts of soluble nitrogen compounds were added to the lake by the Maumee River. There was no oxygen depletion at the mouth of the Detroit River and the nitrogen content was low because of the great volume of water in this river compared to the volume of sewage added to it.

Maumee Bay was found to be a center of production for both phyto- and zooplankton. The plankton crustacea were nearly twice as abundant here as in the open lake, and more than fifteen times as abundant as at the mouth of the Detroit River. The abundance of plankton in Maumee Bay is presumably the result of the large amount of nitrogen compounds available. The paucity of plankton at the mouth of the Detroit River is explained by the facts that Lake

St. Clair is plankton poor and that there is no opportunity for production in the river itself.

In the open lake the principal bottom organism was the mayfly, Hexagenia. Near the mouths of the rivers this form was replaced by tubificid worms, which are recognized as highly tolerant to pollution. Using the number of worms as a criterion, the polluted area was divided into zones of heavy, moderate, and light pollution. Heavy pollution was found only at the mouths of Maumee and Raisin Rivers, and the total area involved was roughly 10 square miles. Moderate pollution was found also at the mouth of Detroit River; the combined area for the three rivers was approximately 20 square miles. Because of the accumulations of decaying organic matter in these two areas of heavy and moderate pollution, they can not be considered highly suitable for spawning grounds of fish. The combined area of the zones of light pollution was roughly 75 square miles. It is believed that the major part of this zone includes a substratum suitable for spawning purposes.

The undesirable effects of pollution have been contamination of the water by sewage bacteria and the reduction of spawning areas, but the harm done to the commercial fisheries by reduction of spawning areas has no doubt been offset, at least in part if not entirely, by the increase in plankton, which serves as food for young fish and for the adults of plankton-feeding species.

LAKE CHAMPLAIN

The chief objective of the Lake Champlain investigation was to determine the effect of commercial seining in Missisquoi Bay by Canadian residents on the abundance of pike-perch in the United States waters of the lake. It was believed that the series of public hearings held by the International Fact-finding Commission at Plattsburg, N. Y., Swanton, Vt., and Phillipsburg, Quebec, on October 15, 16, and 17, respectively, would complete the field work; but after a conference at Phillipsburg, Quebec, of the State and Provincial officials involved, it was found necessary to collect additional data, with special reference to sexual maturity of yellow pike-perch and the abundance of whitefish in Vermont waters. In cooperation with the State of Vermont, Doctor Van Oosten carried on the necessary seining experiments at Larrabees Landing and its vicinity during the period October 26 to November 16, 1931. Most of the data collected previously during this investigation have been analyzed in the laboratory; and as soon as other duties permit, the final report with recommendations will be submitted by the commission.

WISCONSIN LAKE STUDIES

STUDIES OF FISH GROWTH

The investigations of the lakes of northeastern Wisconsin which the bureau conducted in cooperation with the Wisconsin Geological and Natural History Survey in 1927, 1928, and 1930 were continued through 1931. During the months of July, August, and early September Dr. Ralph Hile, of the bureau, and Edward Schneberger, of

the Wisconsin survey, with the aid of two assistants, collected data for growth study from 7,764 fish. These collections were made from six " type " lakes in which the growth rates of the perch, rock bass, and cisco are being studied. The policy of distributing scale envelopes to sport fishermen for the purpose of obtaining data on the game fish of the region was continued.

Since preliminary study indicated the possible existence of distinct races of ciscoes in the different lakes, a total of 720 specimens from five lakes were preserved for purposes of morphometric study.

The question of the existence within a single lake of local races having different growth rates was attacked from two angles. In Muskellunge Lake, which has a rather complex basin, collections of scale material were made in two widely separated bays. In the same localities 1,400 rock bass, bluegills, and perch were tagged. Since the tagging operations were conducted late in the season, the recoveries were not numerous. It is hoped that later recoveries may lead to conclusive results on the question of the extent of the wanderings of these species within the lake.

COOPERATIVE LIMNOLOGICAL INVESTIGATIONS

Physical, chemical, and biological studies of several of the lakes of northeastern Wisconsin were continued in the summer of 1931. The Trout Lake Laboratory of the Wisconsin Geological and Natural History Survey was opened on June 28 and the investigations continued until September 10; the fish work extended to September 18. These studies are entirely supervised and largely financed by the survey; but, in recognition of the bureau's modest cooperation, the following report is submitted by Prof. Chancey Juday and, because of its interest in relation to hydrobiological and aquicultural research in which the bureau is engaged, is published here.

The field party consisted of E. A. Birge, C. Juday, Edward Schneberger, F. H. Couey, S. X. Cross, George E. Burdick, J. B. Goldsmith, H. C. Baum, and K. A. Siler, biologists; F. L. Taylor, chemist; and W. L. Hafner, part-time surveyor and cartographer. In addition, Leslie Titus was employed in making chemical analyses of the lake residues in the chemical laboratory of the University of Wisconsin during the summer. The staff of the Bureau of Fisheries that took part in these cooperative investigations consisted of R. O. Hile, H. M. Field, and William Duden.

With the exception of the work on the transmission of solar energy by these lake waters, the investigations were confined chiefly to the six lakes that were selected for an intensive study of their fish fauna. Observations on solar-energy transmission were made on a number of other lakes, representing various types, in addition to those that were made on the six lakes selected for the fish studies.

A more sensitive reading instrument was used during the summer of 1931 for the observations on solar-energy transmission through these lake waters, so that it was possible to obtain results at greater depths. With the present galvanometer readings can be taken where the amount of solar energy is only about 0.001 per cent of that delivered at the surface of the lake. The results obtained at these greater depths serve to give a much better picture of the light and turbidity conditions in the lower strata of some of these lakes, and their relations to the photosynthesis that takes place in the deeper water. By the use of color screens, also, it is now possible to determine the quality as well as the quantity of light at different depths.

Excess oxygen produced by chlorophyll-bearing organisms has been found in a few of these lakes down in the region of the thermocline and the upper part of the hypolimnion, and these solar-energy observations have a direct bearing

upon the problem of photosynthesis in these strata as well as in the deeper water. In Crystal Lake, for example, abundant growths of the moss *Drepanocladus aduncus* var. *aquaticus* are found on the bottom at depths of 18 to 21 meters, and similar growths of this plant are found in Weber Lake at depths of 11 to 13.5 meters. Such growths of plant material at these depths raised the question of the amount of solar energy present there for the process of photosynthesis. A number of observations taken in different years and at different times during the summer show that from 1 to almost 4 per cent of the solar energy that is delivered to the surface of the lake penetrates to a depth of 20 meters in Crystal Lake, while nearly 2 per cent reaches a depth of 13 meters in Weber Lake. These amounts of energy seem to be sufficient to enable this moss to carry on photosynthesis and grow profusely at these depths in spite of the fact that the summer temperature of the water varies from 7° to 12° C. at 18 to 20 meters in Crystal Lake, and from a little less than 9° to 15° at 13 meters in Weber Lake in the different years.

A stratum of water possessing an excess of dissolved oxygen was found in Silver Lake on August 28, 1931, and this excess represented oxygen that had been liberated in this region through the photosynthetic activities of the phytoplankton. The quantity of dissolved oxygen at 9 meters on this date was 13.2 milligrams per liter, which was equivalent to 127 per cent of saturation, and there was also a slight excess at 10 meters. Solar-energy readings taken during the summer showed that about 1¼ per cent of the amount of energy delivered to the surface of the lake penetrated to a depth of 9 meters and somewhat less than 1 per cent reached 10 meters. These results seem to indicate that the phytoplankton as well as the moss Drepanocladus are able to carry on the process of photosynthesis in the lower strata of a lake when the solar energy is reduced to about 1 per cent of the amount delivered to the surface.

Regular observations were made on the temperature and dissolved gases of the six lakes selected for the fish studies. Dissolved oxygen determinations were made for the purpose of obtaining some idea of the most suitable strata for fishing operations in the various lakes; this was true especially in Muskellunge, Nebish, and Silver Lakes, where there is a paucity of oxygen in more or less of the hypolimnion during the summer period of stratification. The general results of such analyses have been incorporated in previous reports, so they may be omitted here.

Some chemical determinations were made on the waters from about a hundred wells and springs situated in the vicinity of the various lakes. These analyses were made for the purpose of obtaining a comparison between the quantity and quality of the substances held in solution by the ground waters and those found in the neighboring lake waters. The general results of these analyses show that the ground water is "softer" than that of the neighboring lake in some instances, in other cases the two are about the same, while in still others the ground water is "harder" than the lake water. Further work on this problem will be necessary before any definite conclusions regarding the relationship between ground and lake waters in this district can be reached. Residues from about a hundred wells and springs were secured during the summer, and further analyses of them will be made at the first opportunity for such work.

The biological work consisted of (*a*) a quantitative study of the plankton of the six selected lakes, (*b*) a quantitative study of the bottom fauna of these lakes, (*c*) a qualitative and quantitative study of the food eaten by the fish, and (*d*) a study of the internal parasites of the fish. Material was also collected for an investigation of the rate of growth of the different species of fish that are found in the various lakes.

Muskellunge Lake yielded the largest average standing crop of plankton organic matter and Clear Lake the smallest, 1.15 grams per cubic meter and 0.58 gram, respectively. The volume of Silver and Weber Lakes has been determined, so that the average standing crop of the entire lake may be computed for them. For Silver Lake the average amount of dry organic matter in the standing crop of plankton was a little over 10,000 kilograms, which was equivalent to somewhat more than 100,000 kilograms of living material; the dry weight represented 115 kilograms per hectare of surface, or 102 pounds per acre, while the living weight was approximately ten times as large.

In Weber Lake the average amount of dry organic matter in the standing crop of plankton was 930 kilograms, which was equivalent to about 9,300 kilograms of living material; these amounts represented 60 kilograms of dry organic matter per hectare, or about 600 kilograms of living material per hectare, which were equivalent to 54 and 540 pounds per acre, respectively. The average standing crop of plankton in Weber Lake was only a little more than 51 per cent as large as that of Silver Lake on the basis of unit area.

Quantitative and qualitative studies of 676 bottom samples were made during the summer. The general survey of the bottom population was completed for five of the lakes, namely Clear, Muskellunge, Nebish, Silver, and Weber; owing to the large size of Trout Lake, much more time will be required to make an adequate survey of its bottom-dwelling animals. One of the interesting facts brought out in the survey was the comparative abundance of the bottom population in the shallow water where the bottom consisted of well-compacted sand and gravel. Such a substratum is generally regarded as unfavorable for insect larvæ, oligochaets, and other macroscopic bottom forms, but on these sandy and gravelly areas the macroscopic population ranged from 100 to more than 4,000 individuals per square meter. In the deeper water where the bottom consisted of mud, or a mixture of mud and sand, the number of individuals varied from none up to a maximum of about 9,000 per square meter. A considerable number of samples from the deepest portions of these lakes did not contain any macroscopic organisms, but all of the shallow-water samples contained at least a few organisms. The chief constituent of the bottom population, both in the shallow water and in the deeper areas, consisted of chironomid larvæ. Snails were especially abundant in some of the shallow-water areas.

The stomachs of 3,000 fish were examined for their food content. Of this number approximately 1,000 were found to be empty, leaving 2,000 specimens for analysis. Among those containing food material, there were 725 perch, 470 rock bass, 233 bluegills, and 273 ciscoes; the others consisted of game fish, minnows, and suckers.

The following table gives the average percentage of the more important items found in the stomach contents of the 725 perch.

Item	Average percentage
Caddis-fly larvæ	22.0
Fish	12.3
Cladocera (chiefly Daphnia)	8.5
Hexagenia larvæ	7.5
Chironomus larvæ and pupæ	6.5
Crayfish	4.8
Amphipods	3.6
Plant material	3.4
Total in 8 items	68.6

The eight items included in the table constituted a little more than two-thirds of the total stomach contents, while a little more than one-third consisted of caddish-fly larvæ and fish. Cladocera ranked third in importance. In addition to the above figures, it may be noted that 7 small perch of the 1931 brood contained 56 per cent Cladocera and 41 per cent Copepoda.

The stomachs of the 470 rock bass contained the following percentages of material.

Item	Average percentage
Dragon-fly larvæ	11.0
Chironomus larvæ and pupæ	9.8
Fish	8.9
Hexagenia larvaæ	7.8
Crayfish	7.6
Caddis-fly larvæ	5.2
Plant material	5.0
Snails	2.5
Total in 8 items	57.8

The results for the 233 bluegill stomachs were as follows:

Item	Average percentage
Plant material	25.7
Chironomus larvæ	22.0
Ants	11.5
Snails	9.7
Hexagenia larvæ	5.1
Amphipods	2.8
Total in 6 items	76.8

These results indicate that the bluegills are much more restricted in their diet than either the rock bass or the perch. The 6 items listed in the table constituted 76.8 per cent of the food material found in the bluegills as compared with 57.8 per cent for 8 items in the rock bass and 67.6 per cent for the 8 items in the perch. The large percentage of plant material found in the stomachs of the bluegills is also an important difference; it amounted to 3.4 per cent in the perch, 5.0 per cent in the rock bass, and 25.7 per cent in the bluegills.

The menu of the 273 ciscoes was still more restricted, as indicated in the following table:

Item	Average percentage
Cladocera	45.6
Copepoda	32.8
Corethra larvæ	2.1
Chironomus larvæ	1.8
Total in 4 items	82.3

Two items, namely, Cladocera and Copepoda, make up more than 78 per cent of the food material of the ciscoes. In 67 ciscoes obtained from Clear Lake, 96.4 per cent of the food consisted of Daphnia. This table shows that there is very little competition for food material between the ciscoes and the other three species enumerated above.

During the summer 2,643 fish from the various lakes were examined for internal parasites. The perch were rather heavily infested in four of the five lakes from which specimens were examined in considerable numbers. The flesh and digestive organs of only 195 out of 652 perch were negative, and 164 of those that were negative came from Weber Lake. Excluding those from Weber Lake, only 6 per cent of the specimens from the other four lakes gave negative results. No explanation of the very small percentage of infestation in the Weber Lake perch has been found so far; only 11 specimens out of 175 harbored parasites. It may be mentioned in this connection that 7 specimens of smallmouth black bass from Weber Lake also gave negative results. A small trematode larva was found in the eyes of 96 per cent of the perch from Trout Lake, in 98 per cent of those from Muskellunge Lake, and in 100 per cent of those from Nebish and Silver Lakes.

The flesh and viscera of the rock bass yielded a high percentage of parasites; the infestation varied from 88 per cent in Trout Lake to 100 per cent in Nebish and Silver Lakes. The small trematode larva was found in the eyes of only 30 per cent of the rock bass from Silver Lake, but this infestation reached 90 per cent in Muskellunge Lake and 100 per cent in Nebish and Trout Lakes.

Trematode larvæ were found in the viscera of all of the bluegills (180 specimens) from Muskellunge Lake, and 20 per cent of them also had cestode cysts; 92 per cent of them had trematode larvæ in their flesh, and 60 per cent had trematode larvæ in their eyes.

Thirty ciscoes from Silver Lake were examined for parasites, and cestodes were found in the intestines of all of them; 80 per cent of them also had Acanthocephala. In Muskellunge Lake 80 per cent of the ciscoes contained cestodes and 20 per cent were free of visceral parasites. In Trout Lake 16 per cent were negative, 82 per cent had cestodes in their intestines, and 10 per cent also had Acanthocephala. The ciscoes from Clear Lake, on the other hand, were 96 per cent negative; only 2 specimens out of 60 examined yielded any parasites. These fish were found to be feeding almost exclusively on

Daphnia, and this may be partly responsible for the very small parasite infestation. Clear Lake also has very soft water, and the snail population, as a result, is relatively small, so that the danger of parasite infestation from this source is correspondingly small. Weber Lake also has soft water and a comparatively small snail population, and this may account, in part at least, for the small number of parasites found in the perch of that lake.

In the investigations relating to the growth of the perch in the northeastern lakes, Edwin Schneberger has read and measured the scales of about 3,000 specimens, from which rates of growth have been computed.

In June, 1931, the following papers relating to the investigations made on Wisconsin lakes appeared in Volume XXVI of the Transactions of the Wisconsin Academy of Sciences, Arts, and Letters.

1. A third report on solar radiation and inland lakes. E. A. Birge and C. Juday.
2. A second report on the phosphorus content of Wisconsin lake waters. C. Juday and E. A. Birge.
3. Copepods parasitic on fish of the Trout Lake region, with descriptions of two new species. Ruby Bere.
4. Leeches from the lakes of northeastern Wisconsin. Ruby Bere.
5. Note on the determination of total phosphorus in lake water residues. Leslie Titus and Villiers W. Meloche.

PACIFIC COAST AND ALASKA FISHERY INVESTIGATIONS

On May 22, 1931, the personnel and equipment of the Stanford University field station of the Bureau of Fisheries were transferred to the new Fisheries Biological Laboratory at Seattle, Wash. All of the bureau's biological investigations, dealing with Pacific coast fishery problems, except those relating to shellfish and the cooperative work on California trout, are now being carried on at this station.

The laboratory building of this new station is constructed of brick and is fireproof throughout. It has three full stories and contains 29 offices for individual workers. The lower floor is taken up with storerooms, photographic dark rooms, the heating plant, a room which can be kept at constant temperature for the storage and space for working on fresh or preserved specimens. The second floor consists entirely of offices. The third floor is composed of additional offices, two chemical laboratories, a fireproof room for the storage of valuable data and a large library. Connections for gas, hot and cold water, steam, compressed air, and vacuum are available in virtually all of the individual offices, so that they may be converted readily into experimental laboratories whenever the need occurs.

The staff of investigators of the International Fisheries Commission, United States and Canada, is occupying quarters in the building at present, and offices for a statistical agent and a technologist and one of the chemical laboratories has been fitted up for use of the division of fishery industries.

ALASKA RED SALMON

Karluk red salmon.—Marking experiments were continued at Karluk, Alaska, during 1931 for the purpose of determining if possible the mortality of the red salmon while the fish are in the salt water and also to provide a check on the readings of the salt-water growth taken from the scales. Fifty-five thousand red-salmon fingerlings were marked as they were migrating to the sea. The commercial

catch was sampled for the return of fish marked in 1928, 1929, and 1930.

In 1930, 55,000 migrants were marked, 50,000 by the removal of one ventral fin and the adipose fin and 5,000 by the removal of the right pectoral fin and the adipose fin. This was the first time the pectoral mark had been used at Karluk. The first returns from this marking appeared this year, and it is of interest to note that the returns of fish marked by the removal of the right pectoral fin and the adipose fin were comparable to the returns of the fish marked by the removal of one ventral fin and the adipose fin; therefore, it appears that the use of this mark will prove to be satisfactory.

The study of the returns from known escapements of spawning salmon was continued. The run of 1931 was, for the main part, the return from the brood year of 1926. The escapement of 1926, 2,500,000 fish, was the greatest escapement of red salmon into Karluk River of which we have any record; and had conditions on the spawning grounds been favorable, a very large run in 1931 undoubtedly would have been produced. The run in 1931 was, however, only fair. That conditions on the spawning grounds were not favorable was noticed by observers in 1926, and their observations were included in the first Karluk report, " Investigations concerning the red salmon runs to the Karluk River, Alaska," by Charles H. Gilbert and Willis H. Rich, in which it was stated in regard to the low water in the Karluk River watershed, " * * * Just what effect this will have on the success of the spawning is problematical; it may be slight or it may be great enough to offset in considerable measure the effect of the fine spawning escapement * * *."

We have, then, two brood years which are somewhat comparable—1924 and 1926. In 1924 the red-salmon escapement was about 1,000,000 fish and the pink-salmon escapement was estimated at over 4,000,000 fish, the pink salmon occupying to a great extent the same spawning grounds as the red salmon. The spawning beds were so crowded, due to the very large escapement, that the result of the spawning was poor. Only a few thousand pink salmon returned to Karluk in 1926 from the spawning escapement of over 4,000,000 fish, and the return of red salmon from this brood year was less than 1 to 1. Overcrowding on the spawning grounds was undoubtedly the chief cause of the poor returns.

The summer of 1926 was unusually dry at Karluk, resulting in a lowering of the level of the spawning streams entering into Karluk Lake and also a lowering of the level of the lake itself. Thus the area of the spawning beds was reduced, and the good escapement of 2,500,000 red salmon caused overcrowding on the spawning grounds. Both in 1924 and 1926 there was noticeable overcrowding, and in both cases the return from the spawning escapement was less than 1 to 1. We are faced, then, with the evidence that too large an escapement is just as unfortunate as too small an escapement.

It must be pointed out here, however, that the evidence can not be interpreted to mean that every time there is an escapement of 2,500,000 red salmon into Karluk River that there will be a poor return, for if climatic conditions at Karluk Lake had been normal in 1926, the spawning grounds would not have been overcrowded.

Three trips were made to Karluk Lake to obtain limnological data and to observe conditions on the spawning grounds. This investigation has been conducted under the general direction of Dr. Willis H. Rich, of Stanford University.

Chignik red salmon.—The season of 1931 proved to be very favorable for the investigation of the red-salmon runs at Chignik, Alaska, which Harlan B. Holmes and assistants have been conducting for the past four years. The run of mature fish, amounting to approximately 1,500,000, was sufficient to permit fishing by the greater part of the traps throughout the season. As a result of this condition it was possible to collect numerous data for age analysis of the run and to study the adequacy of sampling. During the two preceding seasons studies of sampling were undertaken, but a poor run in 1930 and the dominance of a single-age class in 1929 made these attempts of little value. The run of 1931 was very favorable, not only as a result of continuous fishing but also as a result of a good representation of at least four age classes. A preliminary study of the data has shown an orderly progression of runs of the several age classes, the fish of a single class starting with few individuals, gradually increasing to a maximum of abundance, then gradually declining until it finally disappears. The overlapping of two or more such independent runs gives the general run a complex and constantly changing age composition. This complexity apparently is increased by the existence of two independent races of red salmon supported by the spawning grounds of the two lakes in the Chignik system. Each of these two races is represented by the four age classes, making a total of eight such classes to be considered in the analysis of the run.

Comparison of the catches of traps on the two sides of Chignik Bay, separated by a distance of approximately 6 miles, shows that traps on one side catch a significantly greater proportion of larger and older fish than those on the other. The reason for this difference is not apparent unless it be that the fish of different ages tend to follow opposite shores of the bay. This evidence of selective fishing further increases the needs for extensive sampling.

Observations of the young fish in fresh water were continued in 1931. Samples of migrants and lake residents were collected at frequent intervals. Approximately 70,000 of the seaward migrants were marked by the removal of fins.

The problem of independent races is proving to be very important at Chignik. It was at first supposed that the spawning fish scattered at random over the entire spawning area and that as a result the entire population represented a single race. More recent observations indicate that the two lakes support separate groups, or races, of fish. Those fish whose parents spawned in the tributaries of one of the lakes seem to return to that lake to spawn, thus perpetuating the independence of the two races. The two races seem to have different habits; for example: One starts its spawning migration earlier in the season. These racial differences probably are responsible for a great part of the complexity of the problems encountered at Chignik. Special attention is to be given to the races during the next field season.

Copper River red salmon.—An investigation of the red-salmon runs of Copper River, Alaska, has been continued by Seton H. Thompson,

assisted by Morris Rafn. This work has been directed toward securing a knowledge of the age groups represented in the runs and their relative importance, the time at which fish bound for the various widely separated spawning grounds pass through the commercial fishery at the delta, and the present condition of the fishery.

A scale study has revealed that the red salmon of the Copper River mature at various ages ranging from 3 to 7 years and live for one to four winters in fresh water before the time of their seaward migration. Only 3 of the 11 age groups represented have been of significance in any of the recent runs. Of these, the fish maturing in five years, which have spent two winters in fresh water, have been the predominating age group. The relative importance of these age groups has changed with some degree of regularity during each season.

For the purpose of determining the time at which the salmon that spawn in the different tributaries pass through the gill-net fishery at the delta, records have been obtained of the daily catch by the commercial fishery at the river mouth, by the Indian fish wheels distributed along the entire length of the river, and by gill nets operated in some of the more important tributaries. The runs, so obvious at the mouth of the river, may be traced to their ultimate destination by this method, and regulations may be promulgated to provide adequate seeding of each spawning area. The collection of uniform statistics has been facilitated by the use of forms prepared for that purpose.

In connection with these observations data have been collected which are designed to show whether or not the salmon utilizing distinct spawning areas of the Copper River develop physical characteristics by which they may be distinguished. The analysis of these data is not yet complete.

An effort has been made to determine the extent of the spawning beds of the river and its tributaries. With this proposition in view, the seeding of the known spawning localities is observed annually. Much of the river system, because of the difficulty of access during the summer months, has not been explored and new spawning areas are being discovered each year.

Bristol Bay red salmon.—A. C. Taft, who was formerly in charge of the Bristol Bay red-salmon investigation, was transferred to other work during the latter part of 1930. T. L. Schulte carried on the necessary field work in this locality during the summer of 1931.

A very extensive collection of downstream red-salmon migrants was secured from Aleknagik Lake, its tributaries, and Wood River. Total length and body measurements have been made of these specimens and samples of the scales have been mounted. These data upon analysis should yield much information regarding the early life history of the red salmon of the Wood River and its tributary lakes and streams.

Scale samples were also collected from adult red salmon caught both in the Wood River system and in the commercial fishery in Bristol Bay itself. Trips of inspection were made to the other principal fishing areas in Bristol Bay.

ALASKA PINK-SALMON INVESTIGATIONS

This investigation is concerned with the study of the life history of the pink salmon (*Oncorhynchus gorbuscha*). During the past year the following experimental studies were pursued under the supervision of Dr. F. A. Davidson:

Application of "parent stream" theory to life history of pink salmon.—The experiments underlying this study consist of marking pink-salmon fry from a given stream as they leave the stream by means of clipping the dorsal and adipose fins from their backs. This is followed by a careful observation of the adult pink salmon, returning to the stream two years later to search for individuals bearing the marks. These experiments were started in the spring of 1930 at the Duckabush (Wash.) hatchery on Hood Canal, where 36,000 pink-salmon fry were marked. In the fall of 1931 the pink salmon that returned to other streams on the canal, as well as those returning to the Duckabush River, were observed for adults bearing the marks. Eight adult pink salmon, consisting of males and females, showing both dorsal and adipose marks were found in the Duckabush River. One adult female was found in the Hamma Hamma River, located just north of the Duckabush River, and one adult male was found in the Docewallips River, just south of the Duckabush River, both of which showed both dorsal and adipose marks. An examination of the scales of these marked salmon showed that the time of their return as adults coincided with their age indicated by the checks on their scales.

In the spring of 1931, in Snake Creek, at Olive Cove, Alaska, 50,000 pink-salmon fry were marked by means of clipping their dorsal and adipose fins. These fry are expected to return in the fall of 1932. The marking experiments in Alaska are being supplemented by racial analysis of the pink salmon in the streams in which fry are marked. During the summers of 1930 and 1931 the pink salmon in Snake Creek and the pink salmon in Anan Creek, a neighboring stream, were studied from the racial standpoint.

Variation in time of appearance of pink-salmon runs in southeastern Alaska.—Through the courtesy of the salmon packers operating in southeastern Alaska, the bureau secured the records of the daily pink-salmon catches of a large number of salmon traps located in the various fishing districts throughout the territory. These records in general cover a period of time from 1908 to 1930, inclusive, and are believed to be representative of the changes that have been taking place in the status of the fishery.

Since the salmon traps are stationary units of gear and more or less permanently located, it was assumed that the time of appearance of the pink-salmon runs in any district would be indicated by the time in the fishing season the pink-salmon catches were made by the salmon traps located in the district. With this assumption in mind, a statistical analysis was made of the daily pink-salmon trap-catch records of the salmon traps located in each fishing district in the territory for the purpose of ascertaining variations in the time of run.

A similar analysis of the daily pink-salmon packs of a southeastern Alaska cannery showed that from 1895 to 1909 the pink-salmon runs were much later than they are at the present time. In

looking over Reports of the Commissioner of Fisheries for these years, numerous references were found concerning the enormous quantity of pink salmon in the territory. Following this period the total yearly packs of pink salmon increased rapidly in the Territory, and it was then that the runs began to come in early. They reached their earliest stage between the years 1914 and 1918, after which their appearance has been increasingly retarded. According to the Reports of the Commissioner of Fisheries, the fishing regulations were enforced more and more effectively after 1918 and, with this increased protection, the pink-salmon runs began to build up. This recuperation of the pink-salmon runs is evidenced by the increase in the average total catches of the traps in a number of fishing districts during this period.

It appears that from 1895 to 1909, when the pink-salmon population in the Territory was at its maximum, in so far as there is a record, the pink-salmon runs were much later than they are at the present time. Then, from 1909 to 1918, when exploitation of the runs was very intensive and the salmon population was greatly reduced, the runs became early. Finally, when the Bureau of Fisheries began to enforce the fishing regulations more effectively and impose more adequate regulations in 1924, the pink-salmon population began to build up and at the same time the runs started to come in later in the fishing seasons. In other words, there seems to be a significant relationship between the size of the pink-salmon runs and the time of their appearance in the fishing seasons.

STATISTICS OF THE ALASKA SALMON FISHERIES

Compilation and analysis of the statistics of the Alaska salmon fisheries has been continued by Dr. W. H. Rich and E. M. Ball, of the Alaska division. A second part of this series was published during the past year and covered the district from Chignik to Resurrection Bay. Part 3, which covers the Prince William Sound area and the Copper and Bering Rivers, has been completed and will be published in the near future. Much of the preliminary work has been done on part 4, which will cover southeastern Alaska and will complete the study of the statistics from the inception of the industry up to and including the season of 1927, from a standpoint of total-catch records.

ALASKA HERRING

In September, 1931, a scientific report was submitted to the bureau for publication by Dr. George A. Rounsefell, in charge of the herring investigation, and Edwin H. Dahlgren, showing the fluctuation in the abundance of herring in the Prince William Sound region of Alaska. The herring fishery of this region has been marked by fluctuations in the abundance, size, and quality of the fish, which have caused heavy losses to the operators. The stabilization of the yield of this fishery is an important economic problem. This report shows clearly that these changes in abundance are caused by inequality in the numerical strength of the annual increments to the population proceeding from each year class and by insufficient numbers of older fish, owing to a too intensive fishery.

The availability of the herring in different portions of the season was carefully analyzed and tables computed showing what percentages of the total catch is taken in each 10-day period. This knowledge is essential, since the amount taken during such a period varies materially through the season. Knowing these figures, it is possible to reduce the total catch any desired percentage by means of closed seasons. The extreme localization of the fishing grounds is shown by an analysis of the catches for eight years (1923 to 1930, inclusive). During this time 50.7 per cent of the total catch was taken in the waters contiguous to the southern end of Evans Island, 46.6 per cent from other restricted localities, and 2.7 per cent from all of the remainder of the immense area of Prince William Sound.

In attempting to discover if these various areas supported independent populations, it was found that the means of the number of vertebræ for various year classes of herring differed significantly. Comparing vertebral-count samples of the same year class only (to allow for annual variations in temperature), it was found that the herring populations of McClure Bay and MacLeod Harbor each seem to differ from the remainder of the herring of Prince William Sound.

Body-length frequencies of the herring from Prince William Sound were available for seven years (1924 to 1930) and age frequencies for six years (1925 to 1930). These length frequencies show clearly the progression, year by year, of size modes, due to the growth of fish of dominant year classes. The year classes are so unequal in abundance that one or two year classes usually constitute the bulk of the catch even though several are represented. Thus the 1926 year class, which was unusually abundant, constituted 78.2 per cent of the catch in 1928, 93.3 per cent in 1929, and 87.5 per cent in 1930.

The fluctuations in the catch caused by these dominant year classes are of great importance to the fishery. During the intervals when no abundant year classes of young fish are present the fishery must be supported by a reserve of the older age groups. Depletion of these older age groups by a too intensive fishery seems to have caused the variations in yield which characterize the fishery during the past few years. Unless protection is adequate to insure a sufficient quantity of older age groups at all times, the fishery can not be maintained without such undesirable fluctuations. In order to insure such a supply of older fish it was recommended that a 48-hour weekly closed season be put into effect, and that the purse seines be reduced from 180 to 150 fathoms in length.

The field work of the herring investigation has been aided very materially by the purchase of a motor vessel in July, 1931, which provides comfortable living quarters and laboratory space. Using this vessel, racial samples were obtained for the first time from Saginaw Bay in Frederick Sound, Gut Bay in Chatham Strait, Point Lull at the eastern entrance to Peril Strait, Point Augusta in Icy Strait, and Anita Bay in Zimovia Strait. Samples of fish for vertebral counts totaling 13,900 are now available from over 40 localities in southeastern Alaska. All of the ages of these herring have been read, and an analysis is now being made of the numbers of vertebræ to determine their racial significance.

The usual annual samples were collected from Prince William Sound. In the Aleutian Islands district Marcus W. Meyers preserved gill-netted samples from Dutch Harbor, and additional frozen samples of purse-seined herring were obtained from Lost Harbor on Akun Island.

PUGET SOUND SOCKEYE SALMON

During 1931 an investigation of the sockeye-salmon fishery of Puget Sound was started under the direction of J. A. Craig, with the intention of solving the following problems: (1) Devising a reliable index to the relative annual abundance of the sockeye salmon in Puget Sound during the past 20 years; (2) the discovery of whether or not regular fluctuations exist in each fishing season from year to year in abundance of the sockeye salmon, and if such fluctuations do occur at what dates they take place; (3) ascertaining whether or not distinguishable races of sockeye salmon pass through the Puget Sound fishery, and if so, at what regular dates during the fishing seasons these racial migrations take place. Since the great majority of the sockeye salmon taken in Puget Sound are fish migrating into the Fraser River to spawn, these races, if their existence can be demonstrated, will be mainly races of sockeye salmon spawned in various parts of the Fraser River system.

Records of daily catches of individual traps in Puget Sound have been collected, and these data are being used to determine indices of annual and seasonal abundance. Since these traps are fixed pieces of fishing gear and have been fished under the same conditions through the period of time covered by the data collected, the average catch per trap per fishing day will be used as the unit of fishing effort in making the annual and seasonal indices of abundance. A great part of the preliminary statistical work has been done, and a publication dealing with this phase of the problem will soon be completed.

ROGUE RIVER STEELHEAD TAGGING

The tagging of steelhead trout in the Rogue River, under the direction of J. A. Craig, was continued through the summer of 1930 and the winter of 1930–31. These tagging experiments were undertaken for the purpose of determining whether or not two separate populations of steelheads inhabit the Rogue River, one of which makes its spawning migration during the summer and early fall months and the other during the late fall and winter. If two races of steelheads spawn in this stream, it appears that they must spawn either in different localities or at different times. Therefore it is hoped that the tagging experiments, which will give definite information relating to the time and extent of the spawning migrations of the fish entering the river at different seasons, will provide material for answering this question.

The returns from the fish tagged during the summer of 1930 confirm those obtained from the 1929 tagging activities, namely, that the fish entering the river during the summer and early fall migrate to the higher reaches of the river and spawn in the upper part of the Rogue River itself, or in some of the higher tributaries.

Because of high water and bad weather conditions, which made it almost impossible to catch the migrating fish, it was possible to tag only 50 steelheads during the winter of 1930–31. One of those tagged fish was recovered in July, 1931, in the upper portion of the Rogue River.

Another attempt is being made to tag these fish during the winter of 1931–32; and until some recoveries are made from that tagging the question of whether or not two separate populations of steelheads inhabit the Rogue River can not be definitely answered.

CONSERVATION OF FISH BY MEANS OF SCREENS AND LADDERS

The activities of the bureau's engineers, Shirley Baker and U. B. Gilroy, in perfecting fish screens and ladders for the conservation of the runs of anadromous and migratory fishes in the rivers of the Pacific Northwest during 1931 included (1) the construction of a revolving mechanical fish screen on the Jocko Canal, Mont.; (2) the preparation of, design, and specifications of a revolving mechanical fish screen for the Sun River Slope Canal in Montana; (3) continued operation of mechanical and electric screens on Government diversions in the State of Washington; (4) assistance rendered the State Commissions of Maine, Oregon, Nevada, and Utah regarding fish screen and ladder problems; and (5) the designing of fishways for Sunbeam Dam, Idaho, and Anan Creek, Alaska, and various other inspections and engineering services on major hydroelectric projects in the Pacific Northwest.

MECHANICAL FISH SCREENS

The revolving mechanical screen recommended and used by the bureau follows the design developed by the Oregon State Commission in 1921, and since that time adopted by the State of Washington. This type was first installed in Ahtanum Canal by the bureau in 1929 and described in previous reports. It continues to be the most satisfactory and reliable type of which we have knowledge, and properly installed is positive in its action. The device is not patented.

Jocko Canal screen.—This year to prevent the serious loss of fish on the Flathead project of the United States Indian Irrigation Service in Montana and to encourage the adoption of this type of mechanical screen in that State the bureau installed such a screen on the Jocko Canal. This canal has a capacity of 300 second-feet. The installation consists of three sections of revolving screen cylinders, each being 4½ feet in diameter and having a width of 10 feet.

The point of installation is 6 miles downstream at the outlet of the lower of two small lakes through which water, diverted into the canal from Jocko River, is passed. The purpose of the installation is to prevent rainbow trout from leaving the lakes, and thus it is hoped to accumulate an attractive supply of fish in those waters.

Sun River slope screen.—In the proposed Sun River slope screen we have the most ambitious attempt yet made in the application of the revolving mechanical screen. The capacity of this canal is 1,435 second-feet. On this project water is taken from Sun River at a diversion dam in a narrow canyon and transported by canal to Pishkun Reservoir. From the reservoir the water is conveyed to the

system through the Sun River Slope Canal. The site selected for the installation of the screen is at a point approximately ½ mile below the outlet of Pishkun Reservoir. At this point the canal widens out into a natural pond, affording favorably reduced velocities just upstream of where it is proposed to stop the fish by means of the screen.

The typical section of the Sun River Slope Canal has a bottom width of 30 feet, and for the capacity flow of 1,435 second-feet the depth of water is 11.5 feet. In order to maintain satisfactorily low velocities through the screen box the design calls for installation of the screen in five sections, each having a width of 14 feet and a diameter of 13 feet. The supporting box of reinforced concrete contains approximately 370 cubic yards of 1:2:4 concrete and approximately 50,000 pounds of reinforced steel. The five sections of screen are driven by three paddle wheels located just downstream from the screen cylinders and connected to the latter by means of chain and sprocket gearing. In the fabrication of the screens and paddle wheels approximately 20 tons of steel are required. The covering of the screen cylinder is to be No. 10 gage galvanized steel or copper wire screening having a ⅝-inch clear opening mesh.

Final working drawings of this screen will be filed with the Reclamation Service so that reference to them may be had by the Reclamation Service on all new projects wherein a fish-conservation problem is involved. This in itself is held to be justification for the time and expense contributed by the Bureau of Fisheries in preparing these plans. It will make possible, at the time that new projects are first planned, for proper fish screens to be provided in the original designs of the diversion structure, which will work both for the conservation of fish and economy in construction.

Cooperating with the Oregon Game Commission, field examinations were made and designs and cost estimates prepared covering mechanical-screen installations for Farmers Irrigation Ditch (capacity 100 second-feet), on Hood River, and C. O. I. Canal (capacity 650 second-feet), Pilot Butte Canal (capacity 450 second-feet), Tumalo Canal (capacity 150 second-feet), Swalley Canal (capacity 125 second-feet), and Arnold Canal (capacity 100 second-feet), the last five named being on the Deschutes River.

In the spring of 1931 the Utah Power & Light Co. applied to the Bureau of Fisheries for aid in solving the fish-screening problem at their Lift Plant, situated on Bear Lake. This lake constitutes one of the largest water-storage projects in the country. The problem involves trout of various kinds which frequent the waters of Bear River and Bear Lake. The situation is a peculiar one. Under the scheme of operation water is lifted from the lake by means of large-capacity, low-lift pumps and discharged through a canal into Bear River, where it flows through a series of power plants. During high stages of the river the flow is reversed, and the canal conveys water from the river through the pumping plant for storage in the lake.

The situation was studied very carefully in the field in company with the district supervisor of the Bureau of Fisheries, the State Game Commissioner of Utah, and the engineers of the Utah Power & Light Co. It was decided that instead of using either electric or mechanical screens, which for an installation of this magnitude

would be prohibitive in cost, the best solution of the problem would be to gradually stock the lake with fall-spawning fish and protect the pumping plant by means of removable steel racks which would have to be held in place for only a short time each year. The company is being asked to provide these racks and to cooperate in bearing the cost of a new hatchery which is to be built on Bear Lake by the Bureau of Fisheries and the State of Utah.

ELECTRIC FISH SCREENS

In three previous reports of this division there is presented the history and development of the electric fish screen and its use by the Bureau of Fisheries up to the start of the irrigation season of 1931.

The experimental work conducted in the sluiceway at Gold Ray power house and at the Fort Klamath hatchery in the fall of 1930 demonstrated the superiority of the insulated type of screen over the old-style grounded installation, and led to the adoption of this improved type on all installations maintained by the Bureau of Fisheries. The improved type of screen consists of a double row of 6-inch diameter pipe electrodes fabricated from No. 20 gage galvanized iron. These electrodes, properly weighted at the lower end, are suspended in the water from supporting cables. The most effective spacing has been found to be 4 feet center to center of pipes in rows with 6-foot spacing between rows. Electrification is accomplished with 60-cycle alternating current at a potential ranging from 55 to 65 volts. Convenient voltage regulation is provided by means of a transformer specially tapped on the secondary side and designed to carry a sustained short circuit.

Three years of operation with the electric screen has disclosed the weaknesses of this type of fish-protective device. The chief difficulty is in the antagonism which is likely to develop in the public mind when some fish are killed or stunned by contact with the electrified water. Such attitude entirely disregards the fact that the electric screen may be operating to save the majority of fish, but it creates a problem in public relations which can not be overlooked. Furthermore, the action of the electric screen can never be expected to be 100 per cent effective as is the mechanical screen. Another difficulty is the patent situation, which raises a restriction which can be avoided by use of the mechanical screen. For these reasons the investigators do not recommend the electric fish screen for general use. In the case of the electric screens operated on United States Government projects in the Yakima country the situation is somewhat different. There the bureau itself operates the screens, giving them very careful attention and supervision, and in Yakima County, Wash., alone the use of the electric screen is free from patent royalties. These Yakima screens undoubtedly save a large proportion of the fish, and it is felt that the continued use of these particular electric screens is justified.

Sunnyside electric screen.—The Sunnyside Canal, main diversion of the Yakima project of the United States Reclamation Service, diverts water from the Yakima River near Yakima, Wash. The capacity of the canal is 1,500 second-feet. The diversion period of 1931 extended from February 20 to October 20. During the period

of maximum irrigation demand, which is also the period of chief migration of fish, this canal carried in excess of 1,000 second-feet.

This screen is of the new, improved insulated type, consisting of a double row of pipe electrodes located in the forebay in front of the headgates. This year the location of the screen was moved upstream and out of the river as far as practicable in order to escape the higher water velocities which existed at the old site.

In addition to this main electric screen there was installed an auxiliary screen of similar type extending out from the upstream end of the main installation at right angles to the shore line for a distance of 24 feet. The purpose of this auxiliary screen is to give a preliminary warning to downstream-migrating fish as they approach the diversion point, and thus it is hoped to divert these fish before they enter the higher water velocities which exist at the main screen.

As previously commented upon, water conditions at Sunnyside Dam at certain times produce very severe operating conditions affecting the electric screen. The crest length of Sunnyside Dam is 500 feet. During practically the entire irrigation season flashboards are maintained along the crest raising the water surface approximately 2.5 feet. At the center of the dam is located a large concrete fishway built by the Bureau of Fisheries in 1929. This ladder constitutes the chief by-pass channel at the Sunnyside installation. It undoubtedly serves many downstream migrating fish, especially those that travel down river along the west shore. However, it has long been recognized as desirable to have a by-pass channel located close to the electric screen which is situated at the east abutment of the dam. To this end, early in July a stem gate was installed in the logway which extends through the dam close to the downstream end of the electric screen.

In the operation of any by-pass at the Sunnyside diversion the main difficulty is lack of water. The irrigation season of 1931 was the most critical short-water year in the history of the Yakima project. The Sunnyside diversion is the lowest Government diversion on the Yakima River, and at times the entire flow of the stream is diverted directly into Sunnyside Canal. At such times practically all the flow comes from storage reservoirs maintained by the Government, and all of this storage water is contracted for and sold to the irrigation interests. When these irrigation requirements exceed the available flow, there is no adequate by-pass flow available for the conservation of fish life.

There were times in the summer when there was practically no overflow, but whenever even a small amount of water was available for this purpose, the ready cooperation of the Reclamation Service insured that it was put through the by-pass channels.

Gold Ray intake screen.—Early in April the intake screen at Gold Ray power house of the California-Oregon Power Co. was put into operation at a point upstream of the trash rack at the intake. This screen, also, was of the improved insulated type, consisting of a double row of pipe electrodes. This year the screen was installed at an angle with the intake in the hope that such location would encourage use of the newly improved north bank fishladder as a by-pass for downstream-migrating fish. It proved, however, that close proximity to the steel trash rack was an unfavorable factor, it being

found that a good many fish were passing through the electric screen and being trapped between it and the trash rack. Accordingly, use of this electric screen was discontinued late in May. It was found that the newly improved fish ladder with its illuminated entrance proved a very attractive by-pass for fish, even without the aid of a screen in the intake.

Gold Ray tailrace screen.—The first electric screen installed by the Bureau of Fisheries in the tailrace of the Gold Ray power plant of the California-Oregon Power Co., was put into operation in the spring of 1929. Its purpose was to keep the mature upstream-migrating salmon and steelhead out of the tailrace waters and headed up the main channel of the river to the fish ladders at the dam. For more than two years this screen operated, keeping the tailrace waters entirely free of upstream migrants and accomplishing its mission substantially without injury to the fish. Upon July 17, 1930, the old grounded type of screen was replaced by the new, improved type, consisting of a double row of 6-inch diameter pipe electrodes. The effectiveness of the new screen was early proved by its successful operation against the fall run of silver salmon and the run of steelhead which continued throughout the winter and spring of 1931.

On May 25 the Bureau of Fisheries was notified by an official of the Jackson County Game Protective Association, a local sportsmens' organization of Medford, Oreg., that hundreds of salmon were being electrocuted at the Gold Ray installation. Investigation was made May 27 and a large number of electrocuted salmon were found in the main channel of the Rogue River below the Gold Ray power plant. At this time, also, some salmon were found ahead of the electric screen in the tailrace. It is evident that these salmon had penetrated the screen very recently, for on April 25, when the site was inspected, a good run of Chinook was in progress, with schools of these salmon leaping in the tailrace just below the electric screen and the tailrace above the screen was entirely free of salmon.

A great deal of publicity had been given to the electrocution of salmon in the Rogue River, and the electric-screen installation was blamed for the condition. After field investigation on May 27 the voltage of the tailrace screen was reduced from 65 to 50 volts, and this potential was maintained for a short period of time, during which observations could be made. On May 30 the officials of this sportsmen's organization, acting without authority from the State Commission of Oregon or the Bureau of Fisheries, prevailed upon the vice president and general manager of the California-Oregon Power Co. to order the screen disconnected. Upon June 1 the electrodes were removed from the water. Upon June 2 and 3 the investigators, in company with representatives of the power company and the sportsmen's organization, inspected conditions in the field. At that time there were at least from 1,200 to 1,500 mature Chinook salmon in the tailrace, these having come in within a few hours after the electric screen had been deenergized. This was striking evidence of the effectiveness of the electric screen in having prevented the entrance of these salmon over a long period of time. At the end of this conference the bureau was advised by the officials of the Jackson County Game Protective Association that reinstallation of the tail-

race screen was not desired. The bureau representatives held that the operation of the electric screen was in no way responsible for the electrocution of the salmon, and pointed to the record of success which this screen had enjoyed for a period of more than two years.

During the conference with this committee and the power company it developed that upon April 16 and May 29 there had been short circuits on a 66,000-volt line at Gold Ray. The Gold Ray plant is grounded into the river and the path of the current for these short circuits was through the river to Grants Pass substation No. 2. This explained the electrocution of the salmon in the vicinity of Gold Ray plant and for a considerable distance down river, for at this time this stretch of the channel was alive with a large run of Chinook Salmon.

A short time later the Oregon Fish Commission, feeling confident that the electric screen was not responsible for the trouble at Gold Ray and having information of similar conditions which had existed upon several occasions in previous years, long before the installation on any electric screen, sought information from the power company as to the occurrence of short circuits in this system. These data, covering a 5-year period, were made available to the Oregon Fish Commission, which in turn presented them to the Bureau of Fisheries for their study. Seeking the best possible advice in this matter, the Bureau of Fisheries retained Prof. F. O. McMillan, research professor of electrical engineering, Oregon State College, to make a thorough investigation of the situation, with special reference to any possible effect which might have been produced by the presence of the electric screen in the tailrace. After thorough study in the field and conference with officials of the power company, Professor McMillan reported under date of August 22, 1931:

> I can assure you at this time that the findings are such that there is absolutely no question in my mind but that the electric fish screen had nothing whatever to do with the destruction of the fish that were killed. You will probably recall that I have frequently called attention to the desirability of having the electric screen entirely insulated, from the electrical system supplying the power, by means of an insulating transformer, and that was the condition of operation of the electric screen at the Gold Ray power plant at the time of the electrical disturbances in question. During my investigation in Medford I personally measured the insulation resistance of the fish-screen transformer and of the conductors and cable supports for the electric screens and found the insulation to be absolutely intact. This means that it would be impossible for any of the ground current of the electrical system during an abnormal electrical disturbance to flow back through the electric screen.

In his comprehensive technical report, under date of October 4, are set forth the indisputable findings, which show:

> (1) That the electrocutions of fish which occurred on April 16 and May 29 were due to ground currents existing through accidental single-phase operation of the 66,000-volt line No. 7 between Gold Ray power plant and Grants Pass substation No. 2, these accidental single-phase operations occurring when attempts were made to reestablish service on line No. 7 following line breaks.
>
> (2) That it was impossible for the electric screen to have conducted any part of the ground currents, because it was insulated from the electrical system by means of an insulating transformer designed for the express purpose of preventing any direct electrical connection with the supply system.
>
> (3) That the operation of the electric screen at the time of the accidental grounds was probably responsible for preventing the destruction of a much larger number of salmon than did occur.

Thus we have absolute scientific proof that the operation of the electric screen was in no way responsible for the electrocution of salmon in the Rogue River and the unwarranted removal of this screen from the tailrace of the Gold Ray plant has deprived the river of an effective means of fish conservation.

Check of fish in Yakima ditches.—Check on the efficiency of the electric screens in the Yakima country is obtained by observation of fish found in the systems. As in the seasons of 1929 and 1930, comprehensive check of fish left stranded in the system at the end of the irrigation season was made and, in addition, during the past summer special checking operations were conducted at strategic points in the Sunnyside and Wapato systems. Likewise, W. N. Wagner, the bureau's inspector, paid close attention to the fishing conditions reported to exist in the canal systems and the rivers and himself fished these waters on numerous occasions for the purpose of obtaining data at first hand.

In the Sunnyside Canal (ditch capacity, 1,500 second-feet); irrigation season February 20 to October 20; main canal, 60 miles long; electric fish screen installed) check of the fish left stranded at the end of the season showed the following: 75 salmon, 807 trout,[3] and 36,300 whitefish.

As in the past, cull fish (suckers, squawfish, chisel mouth, etc.) predominate all other types. The great amount of whitefish found this year as well as last indicates that the electric screen is not efficient against this species. It is the opinion of competent observers that the bulk of the whitefish enter the system when they are very small (perhaps about 1½ inches long), which is the time when the electric screen would be least effective against them.

In addition to this comprehensive check made at the end of the season, a special check was conducted early in the summer in lateral 71.66 (Benton extension) at the lower end of the Sunnyside system. This location was the point at which some 10,000 young salmon were reported last year. The check was made by placing a stationary screen at an irrigation drop. The check was continued over the 71-hour period from noon June 18 to 11 a. m. June 21, during which period observers were in constant attendance. The flow of the lateral at the checking point was 35 second-feet. Results showed but 36 young salmon, no trout, 3 whitefish, and 517 cull fish. This check was made at a time when large schools of young salmon and trout were observed near the intake at Sunnyside Dam.

Salmon and trout were especially numerous in the Yakima River this year, and the small number of anadromous fish found in the system indicates that the electric screen functioned to prevent the loss of a large percentage of these fish.

The best possible comparison between fish conditions as existing on a screened and unscreened diversion in the Yakima country is furnished by the check upon the Tieton and Selah-Naches systems. On the Selah-Naches Canal, diverting about 300 second-feet and operated by a private irrigation company, there is no screening device of any kind installed. Two checks of fish left stranded in the Selah-

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[3] Total of 807 trout includes 400 reported by a local fisherman who, with rod and line, fished along 12 miles of canal and reported his own catch and those of several other fishermen as well.

Naches Canal were made this fall. The first count was made during the first shutdown of the season, which extended over the period September 16 to 20. The actual count of fish recovered was: 3,748 salmon, 543 trout, 1,142 whitefish, and 877 cull fish.

Upon September 21 the Selah-Natches again began to divert water. Approximately one month later the canal was shut down for the season. Check of fish actually recovered from the system at this time showed 825 salmon, 122 trout, 348 whitefish, and 139 cull fish.

Thus it is seen that this unscreened diversion taking water from the Naches River under conditions similar to those existing at the Tieton diversion disclosed a total of 5,238 salmon and trout, as against a total of 514 salmon and trout left in the Tieton system in which the electric screen had been in operation for only 141 days out of a total of 251 days.

FISH LADDERS

The activities conducted by this investigation in connection with fishways during 1931 include:

(1) Operation of fish ladders on Sunnyside and Wapato Dams on Yakima River.

(2) Design of fishways for North River project, Washington.

(3) Inspections and supervision of fishway construction at Rock Island project on Columbia River.

(4) Survey of fishway requirements for the State of Maine.

(5) Investigations and design of fishway for Sunbeam Dam, Idaho.

(6) Investigation and designs for improvement of channel at Anan Creek, Alaska.

In 1929 the bureau installed a reinforced-concrete fish ladder of large-pool design at the Sunnyside Dam of the United States Reclamation Service. In 1930 a similar structure was built to our design at the Wapato Dam of the United States Indian Service. Both these ladders on the Yakima River have been under the close supervision of the bureau. They have continued to function perfectly in passing the several large runs of salmon up the river without delay.

Proposed fishway for Sunbeam Dam.—Last spring the aid of the Bureau of Fisheries was asked by the Fish and Game Commission of the State of Idaho in the matter of the fishway problem existing at Sunbeam Dam on the upper Salmon River near Yankee Fork. The dam is of the concrete-arch type, approximately 30 feet high.

The scheme proposed by the bureau utilizes the present diversion tunnel as part of the fishway structure and will not in any way injure or impair the value of the property of the Sunbeam Mining Co.

Fishway problem at Anan Creek.—During the season of 1930 it was found that at certain water stages on Anan Creek, Alaska, the upstream-migrating salmon had considerable difficulty in ascending the channel, due to the presence of natural obstructions consisting of rapids and falls. Accordingly, in July, 1931, field examinations and surveys were made and a design worked out for the improvement of this condition. It was found that the principal obstruction occurred along the stretch of channel extending from the present log dam (situated 500 feet downstream from the counting weir) a distance

of approximately 200 feet upstream to the head of the Upper Falls. The rise in water surface along this 200 feet of channel is normally about 12.8 feet.

The most practical solution of the difficulty is held to be by use of timber dams constructed of heavy logs faced with planking. The installation of three such new log dams along the critical stretch of channel was recommended.

NEW AND PROPOSED POWER PROJECTS

A matter of fundamental importance to fish conservation is the provision of proper equipment for the safe handling of fish at hydroelectric power developments. A good share of the activities of this investigation has been devoted to this work at new and proposed projects in the Northwest. During 1931 the following major developments claimed attention:

(1) Rock Island development of Puget Sound Power & Light Co. on the Columbia River, Wash.

(2) North River project of Western Washington Electric Light & Power Co. on North River, Wash.

(3) Ariel development of Inland Power & Light Co. on Lewis River, Wash.

(4) Cascade Rapids projects (application of Columbia River Power Co. and application of Charles O. Lentz et al.) at Cascade Rapids on Columbia River.

The Rock Island project.—The original requirements for fish protection as written into the project license of this major power development of the Puget Sound Power & Light Co. on the Columbia River near Wenatchee, Wash., called for the protection of both the intake and tailrace waters by means of electric fish screens. However, with the completion of the power house and east-channel spillway dam, in the winter of 1930, opportunity was afforded for the study of physical conditions at the site, and it became evident that there was good possibility that migrating fish might safely negotiate the waters about the power house without the aid of electric screens. Conferences were held with the engineers of the Stone & Webster Co. in Boston, and after thorough study it appeared that in fairness to the company immediate installation of the electric screens should not be required, but that a trial period of operation should be allowed to determine whether or not such equipment would be necessary.

Under date of September 4, 1931, the company obtained an amendment to their Federal Power Commission license providing for change in the plan of development. As regards safety, location and design and relocation of the dam have made possible the construction of a fish ladder offering many advantages over the structure originally proposed for the west channel.

The lower portion of the new ladder consists of a series of pools excavated in solid rock and the upper portion is of reinforced concrete exactly similar to the fish ladder at the power house, the grade being 1 to 10 and the pools being 10 feet long by 20 feet wide and providing for minimum depth of 4 feet of water. Under the new plan of development ultimate pond elevation has been set 4 feet lower than the height originally proposed.

Test of the Rock Island fish ladders will be had with the arrival of the 1932 run of Chinook salmon. By that time construction work will have been completed and the condition of initial development will exist.

North River project.—As commented on in our report for 1930, the North River project proposed the development of 37,500 horsepower by the construction of a concrete dam 112 feet high on the North River, in Pacific County, Wash. Following field inspections and conferences with officials of the Division of Fisheries, State of Washington, and the Pacific coast representatives of the power company, conferences were had in New York in January, 1931, with George Waesche, chief designing engineer of Sanderson & Porter, the engineers for the project, and details of fish-protective devices were worked out.

The plan proposes mechanical handling of both upstream and downstream migrating fish. For collecting the upstream-migrating fish a trap pool is located on the downstream side of the power house and directly over the tailrace. Entrance to this pool is provided for through an 8-foot weir gate which is float controlled to give automatic adjustment to tail-water level. This trap pool leads along the downstream face of the power house to a collecting pool at the toe of the dam. Into this collecting pool a hoisting bucket submerges and water, pumped from the tailrace, flows from the bucket and collecting pool out through the trap pool to serve as an attraction for the fish. When a sufficient number of salmon have entered the bucket it is hoisted on an inclined track up the face of the dam and dumped into the reservoir through a metal chute through which a flow of water is maintained.

The downstream-migrating fish are to be passed from the reservoir to tail-water through six 12-inch intake pipes connecting with an 8-foot standpipe on the downstream face of the dam.

Market conditions have delayed the construction of this project; but when work is undertaken, the action of the fish-protective devices is expected to draw considerable attention, for the operation of this project will afford the first large-scale test of the mechanical handling of both upstream and downstream migrating fish at high dams.

Ariel development.—This season saw the completion of the initial stage of the Ariel development, planned for an ultimate capacity of 180,000 kilowatts and situated on the Lewis River, a tributary of the Columbia River, in Washington. This fall the first 40,000-kilowatt unit went into operation and the initial test of some novel devices for fish protection was afforded with the arrival of the fall run of salmon. Here the dam is 180 feet high, and a carefully planned and comprehensive scheme of mechanical handling has been worked out in lieu of the construction of a fish ladder. The scheme involves trapping of the upstream-migrating salmon and the ripening, spawning, and rearing of these fish on a very large scale.

The feature of principal interest to designers of fishways is the trap pool for collecting the upstream-migrating fish. This pool extends along the downstream face of the power house directly over the tailrace. Entrance to this pool is afforded through three 10-foot entrance gates, which, by means of float control, automatically adjust themselves to tail-water level. Water pumped from the tailrace is

discharged into the upper end of the collecting pool, and the attraction of this flow brings the fish into a hoisting tank, which in turn is loaded onto a truck for transporting the fish to the ripening ponds. The automatic gates have been found to function very satisfactorily and the fall run of salmon passed from the tailrace and into the trap pool without delay. The success of this type of installation for collecting upstream-migrating fish from tailrace waters is most encouraging and would seem to indicate that the solution of the problem of handling fish at high dams lies in the use of equipment of this kind.

Cascade Rapids projects.—At the present time there are two applications pending before the Federal Power Commission for preliminary permit for a power development at Cascade Rapids. Both projects proposed the development of large blocks of electric power by the construction of low dams and diversion works at the crest of Cascade Rapids in the Columbia River.

If such a development is ever undertaken here, very liberal provisions for fish protection should be insisted upon, especially in the matter of by-passing a large flow of water.

SALMONIDÆ OF NEW ENGLAND

Throughout the past year Dr. W. C. Kendall, senior ichthyologist of the bureau, has continued his studies of the salmonoid fishes of New England at the laboratory at Freeport, Me. Three distinct problems which have engaged his attention for many years have been continued. The study of the smelt of New England, except for observations in brooks and streams during the annual spring runs, has been temporarily laid aside in order to give attention to the completion of a study on the salmon, and for analysis of an extensive collection of trouts or chars of North America. As a result of these efforts in the interest of conserving the New England smelts, which have suffered marked depletion in recent years, the last session of the Maine Legislature finally passed regulations which it is believed will be effective in protecting the spawning runs of fish in fresh-water streams.

Landlocked salmon.—A manuscript on the landlocked salmon has been completed and submitted to the Boston Society of Natural History for publication as Part II of a memoir on the Salmonidæ of New England, and will be published as a quarto volume with handsome colored illustrations. This memoir pertains to the origin of the fish, the reasons for regarding it as a distinct species, and the known facts concerning its life history.

Concerning its origin, it is hypothetically argued that it is the product of the stage of fresh-water inundation following the last glacial period, when great estuaries and extensive inland areas of salt water were transformed by melting ice into inland fresh-water seas which gradually shrunk to the recent lakes naturally inhabited by the landlocked salmon. To those conditions the fish was compelled to adjust itself or "go fossil," so to speak. In fact, it might be regarded as a living fossil, which is implied in the name very appropriately given it by Malmgren, who called it *Salmo relicta*. It was left behind, as it were, by the receding marine environment and

underwent physiological changes, one of which, perhaps, was the lost power of the young to undergo the transformation from parr to smolt, which immunizes the young of the sea salmon against any harmful effects in the transition from fresh to salt water.

In addition to all the other evidence, and there is considerable, that the lake salmon (the preferred designation) should be regarded as a distinct species, tables of percentages of proportional measurements were prepared and analyzed, and comparison made with like proportions of sea salmon. Some of the proportions show no differences whatever, excepting those due to sex, age, or size of the fish. In fact, it is only by averages that any of the proportions show differences, for they all overlap as they do with other species of Salmonidæ. There seems to be no possible way to describe an individual salmonid in terms of proportions by which a species can always be positively identified, but the *ensemble* of proportions, after elimination of variations due to sex, size, and age, when expressed in averages, tells the story. One authority on the sea trout of Europe (*Salmo trutta*) states, in effect, that it can not invariably be distinguished from *Salmo salar*, but there can be no doubt about their being distinct species.

In one set of proportions the landlocked salmon differs from the sea salmon (by averages) in exactly the same way that *Salmo trutta* does. This is in the proportion of the part of the body known as the caudal peduncle, which in the landlocked salmon averages much stouter than that of the sea salmon. The difference is most clearly shown by averages of the percental proportions of the least depth of the caudal peduncle to the distances from adipose and anal fins to caudal, as above mentioned. These proportions are greater in the male of both species than in the females, but the differences between the two species are maintained in both sexes.

Chars.—As in the case of other Salmonidæ, there has been no uniformity and stability of classification of the chars (Salvelinus and others). One reason for this is that no one has had an adequate view of the whole field, and, therefore, individual opinions have been based upon glimpses only of the situation outside of immediate surroundings.

In ichthyology generally, both European and American systematists have been more or less at variance in their interpretations and manner of expressing what they saw. In both countries, but more particularly in Europe, there have been two schools of systematic ichthyology. The tendency of one, which was the larger school, was to reduce the number of nominal species to its lowest terms. That of the other was to multiply them particularly as pertained to local faunas.

Thus there have been those who have regarded all the chars of Europe as constituting a single species, with local variations. Others, especially in Great Britain, have discerned in those variations characters regarded as of specific significance.

The single species advocates have extended their conception of that species to include chars of the Arctic regions of both Europe and North America whenever they have had the occasion to consider them. In America the same tendencies have obtained, but not always consistently.

Some years ago Doctor Kendall undertook to bring order out of the prevailing inconsistencies and attendant disorder as pertained to the chars and collected specimens from everywhere possible, far and near. The leaders of various Arctic expeditions were importuned to bring as many specimens as conditions permitted, but very few were obtained from any one locality. However, in the long run, with a few from here and there, a good many specimens have come to hand. The few specimens from scattered localities furnish links, which in time others may be able to unite in a more continuous chain, but it never can be complete, for many links are irretrievably lost through neglect. The fish are extinct, and, in one instance at least, there is not a preserved specimen in existence. It is the purpose of the present work on the chars to place all available links in the sequence that the study of them seems to indicate.

INVESTIGATIONS IN AQUICULTURE

Investigations in fish culture and related problems were considerably extended during the past year. This was made possible by an increase in the personnel and in the facilities for experimental work. These investigations include studies pertaining to all phases of fish-cultural activities. Naturally special attention is paid to problems relating to hatchery operations, but the work is by no means confined to this field. It is becoming more and more evident that fish-cultural activities must be extended to include the welfare of fish after they leave the hatchery. This necessitates a thorough knowledge of conditions in the waters in which fish are to be planted so that a scientific stocking policy can be developed which will insure an adequate return for the labor and money expended in fish-cultural operations. It is becoming apparent also that in many instances much can be done to improve conditions in natural waters so that they will support a larger fish population than at present. Owing to limited personnel it has been impossible to devote much attention to these larger problems in the past; but with the increased facilities now available, it is hoped to place more stress on work in this field.

The fish-cultural stations at Fairport, Iowa, Pittsford, Vt., and Leetown, W. Va., which are operated primarily for experimental purposes, will serve as headquarters for investigators who will not only devote their time to carrying on investigations at their respective stations but will also conduct field studies in the streams and lakes of the surrounding territory.

It is not intended, however, to limit investigations to these experimental stations, but investigators will be stationed at hatcheries in various parts of the country where they will carry on experiments and studies dealing primarily with local problems. These investigators will also be available to render assistance to both Federal and State hatcheries in their respective territories.

The activities of the Fairport station are almost entirely confined to the study of problems connected with pond-fish culture, while those of the Pittsford station are limited to trout culture and its attendant problems. The new station at Leetown, W. Va., is designed for work with both trout and the so-called warm-water fishes; but, owing to insufficient funds to develop the pond system, the work for

the present will be devoted largely to trout, especially rainbow and brown trout, which are not dealt with to any extent at the Pittsford station. Arrangements have also been made to station an investigator temporarily at the State hatchery, Hackettstown, N. J., where a number of bass ponds have been made available for experimental work.

POND-FISH CULTURE

FAIRPORT STATION

The facilities of this station, which is operated under the direction of Dr. A. H. Wiebe, have recently been increased by the construction of a number of new ponds which were in use for the first time during the summer of 1931. Several of the old ponds have also been rebuilt, which has greatly increased their efficiency. The main water supply is pumped from the Mississippi River into a reservoir, whence it is carried by gravity to the ponds. There is also a limited supply of well water which is available for use in several of the smaller ponds.

Black bass.—The bass production was not as satisfactory as in previous years, owing to exceptionally cold weather in the spring, which interfered with spawning and caused the fish to leave the nests shortly after the eggs were laid. The cold weather also delayed the spawning of many of the fish, causing more variation than usual in the size of the fry. As a result, there was an increase in cannibalism, and the percentage of fingerlings which survived until fall was considerably less than usual. The decreased yield in numbers was partially offset by the better quality of the fingerlings, which averaged larger than usual. There was an exceptionally large number of fingerlings around 6 to 7 inches in length.

One of the greatest problems in bass culture is to reduce the number of these large fingerlings. They are undoubtedly cannibals and are probably responsible for a large part of the losses which normally occur during the summer. The use of forage minnows tends to produce a more uniform growth in the fingerlings, and the percentage of exceptionally large fish is considerably less, but during the past season this was in large part nullified by the abnormally long spawning season, resulting in fry differing greatly in age which afforded unusually favorable conditions for cannibalism.

In spite of the unfavorable conditions the production of fry by 2-year-old bass was better than expected, the average number per female being about 1,800. These fish averaged less than one-half pound in weight in the spring, but more than doubled their weight during the summer.

A comparison of golden shiners and blackhead minnows as forage for smallmouth bass showed that, as in the case of the largemouth, the shiner is much superior for this purpose. In a pond stocked with shiners the yield of smallmouth fingerlings was at the rate of 12,575 per acre, while in adjoining pond stocked with blackhead minnows but in every other way treated the same the yield was only 7,215 per acre.

Crappie and bluegill sunfish.—Several ponds were stocked with crappie and bluegill sunfish, and the results agree with those of previous years in indicating that this is an excellent combination

In this case the bluegills serve as forage fish for the crappies, and appear to be better suited for this purpose than either the golden shiner or the blackhead minnow. The best production of black crappie fingerlings was at the rate of 20,562 per acre. In addition there were 1,430 exceptionally large bluegills, making the total production of crappie and bluegills approximately 22,000 per acre.

As regards weight, however, the best production was obtained in a smaller pond, where the yield of black crappie and bluegill sunfish was at the rate of 260 pounds to the acre. This is the largest yield of strictly game fish which has been obtained at Fairport. In comparing these figures with the production at other hatcheries, it should be remembered that no food was added to either pond other than a small amount of fertilizer and that the output represents the actual amount of fish flesh produced in the pond.

The results in both bass and crappie ponds indicate that a fairly abundant growth of submerged vegetation is required for best production. In all ponds showing a satisfactory yield of fish there was a good growth of this type of vegetation, but ponds with scanty vegetation or with a predominant growth of emergent plants were less productive.

Forage minnows.—Observations on the blackhead minnow have yielded some very interesting results. It was found that the activities of the male on the nest not only serve to protect the eggs from various enemies but also to keep up a continuous circulation of water and that the eggs soon die when the male is removed. This minnow is very prolific and a single female may deposit several thousand eggs during the season. One female under observation deposited no less than 4,414 eggs. These eggs were not all deposited at once but at 11 different times during the summer. A surprising result was the discovery that young blackheads hatched early in the season may mature and spawn when only 2 months old.

Effects of high oxygen concentrations and changes in pH.—A series of experiments have been conducted by Doctor Wiebe to determine the effects on fish when the atmosphere above the surface of the water is replaced with pure oxygen. The use of oxygen instead of air when fish are to be shipped long distances is constantly increasing, but the technique employed still leaves much to be desired. Ordinarily the oxygen is forced into the water at the bottom of the container and allowed to escape from the surface. This, of course, results in a great waste of oxygen. It is also claimed by some fish culturists that the gills are affected by the oxygen and may become seriously inflamed.

In view of these facts it was decided to try the effects of high concentrations of dissolved oxygen by placing the fish in a closed container and replacing part of the water with oxygen at various pressures. Several species of fish were used in these experiments, including large and smallmouth black bass, crappie, bluegill sunfish, goldfish, and golden shiners. It was found that all these fish could tolerate an atmosphere of pure oxygen over the surface of the water even when pressures as high as 10 to 15 pounds were maintained for a period of 24 hours. Dissolved oxygen concentrations as high as 41 parts per million were obtained in these experiments without injury to the fish. It was also found that sudden transfers from

high to low oxygen concentrations, and the reverse, had no injurious effects. In several instances fish used in these experiments were kept under observation for several weeks, but in no case were there any indications of injury to the gills.

The experiments also showed that fish can tolerate a high carbon-dioxide content, provided there is also a high concentration of dissolved oxygen. In some instances the CO_2 content rose to over 50 parts per million without any apparent detrimental effect.

These results have a very practical bearing, since they indicate that it will be possible to ship fish for long distances in closed containers with an adequate supply of oxygen stored under pressure. Further experiments in this direction are planned for the near future.

Experiments on the effect of sudden changes in hydrogen-ion concentration (pH) on several species of fish show that they are able to withstand rapid and extensive changes without any injurious effects. Goldfish and green sunfish tolerated rapid changes from pH 7.2 to 9.6 and from 8.1 to 6.0. Fingerling bass were apparently unaffected by rapid changes from pH 6.1 to 9.5 and also by a similar change in the reverse direction. The experiments show that these species of fish can tolerate the entire pH range of most unpolluted lakes and rivers, and hence that hydrogen-ion concentration has very little if any direct effect on the distribution of these fish in nature. The results also indicate that no bad effects need be anticipated in stocking natural waters when the fish are suddenly transferred to a water with a quite different pH from that in which they were reared.

UPPER MISSISSIPPI WILD LIFE AND FISH REFUGE

Investigations in the sloughs of the Mississippi River bottoms in the vicinity of Trempealeau, Wis., were continued during the summer of 1931 under the direction of E. W. Surber.

As was the case at the Fairport station, three periods of unseasonably cold weather during the spawning season proved disastrous to the eggs of the black bass. The number of fry which hatched was so small that it was impossible to utilize most of the sloughs which had been prepared for stocking with bass. Only about 40,000 fry were obtained; and owing to unfavorable conditions in the sloughs as a result of the abnormally hot, dry summer, only 5,330 fingerlings were recovered in the fall. Conditions were more favorable for bluegill sunfish, and Long Pond, which was stocked with 140 adults of this species, produced 40,000 fine fingerlings. A much higher production was obtained in Pickerel Slough, which yielded 320,000 fingerlings from 135 adults.

Principally on account of their feeding habits, gizzard shad have been frequently recommended as an ideal forage fish. It has, however, been impossible to get these fish to propagate in small bass ponds, several attempts of this nature at Fairport having been attended with failure. In the hope that the sloughs would afford more favorable conditions, two ponds were stocked with large adult shad early in the spring. These fish spawned successfully and large numbers of young were produced in both ponds. They grew very rapidly, however, but it is questionable if they would make a satisfactory food for young bass of the same season. On the other hand,

it is possible that the gizzard shad will prove of value for use with yearling and older bass.

Determinations of soluble phosphorus, nitrite, and nitrate ammonia, organic nitrogen, and hydrogen-ion concentrations were made at 10-day intervals throughout the summer in 11 sloughs. Plankton samples were collected every 10 days, while bottom samples were taken monthly in the same sloughs. A report covering these and similar observations in the sloughs during previous years will soon be ready for publication.

Two sloughs were fertilized regularly with sheep manure and superphosphate. Although no bass fry were available to stock these ponds, the effects of the fertilizer upon the bottom fauna and plankton were studied in detail.

Whether connected directly with the river or not, the sloughs are dependent on the river for their water supply; and when the water is exceptionally low throughout the summer, as in 1931, conditions may become very unfavorable for game fish. On the other hand, during exceptionally high flood stages it is frequently impossible to prevent the fish from escaping into the river. For these and other reasons it is felt that under present conditions it is not economically feasible to utilize these sloughs for the propagation of fish and that efforts in this direction had best be abandoned for the present. A potent factor in reaching this decision is the fact that with the construction of the 9-foot channel, which is scheduled for the near future, conditions along the river will be so changed that utilization of the sloughs for fish cultural purposes will present quite different problems from those confronting us at the present time.

HACKETTSTOWN STATION

During the spring of 1931 arrangements were made for cooperative investigations in bass culture to be conducted at the State hatchery, Hackettstown, N. J. Accordingly, Dr. Paul R. Needham was detailed to the Hackettstown hatchery in June and immediately began systematic observations on a number of ponds in which bass were being reared. Although the investigations were not begun until late in the season, some very interesting results were obtained in two ponds which had been used for holding trout during the winter.

One pond which had been used for eight winters as a trout pond was much richer than the other, the bottom being covered to a depth of several inches with a layer composed of trout excrement mixed with silt and muck. After the trout were removed a dense growth of Daphnia developed. Both ponds were heavily stocked with largemouth bass fingerlings late in June and the fish were allowed to remain until August. In the richer pond the growth of Daphnia was so abundant that but little diminution in their numbers was noted over the entire period of 38 days that the bass remained in the pond, so that there was always plenty of food available. In the other pond, however, the growth of Daphnia was insufficient to supply the needs of the bass, and it was necessary to introduce large quantities from another pond. In both ponds there was a large growth of midge larvæ and sowbugs in addition to the Daphnia.

An examination of the stomach contents of fish from both ponds showed that approximately one-half the food consisted of Daphnia,

the remainder being made up mostly of midge larvæ and sowbugs. The fish in both ponds made a rapid and remarkable uniform growth, the average increase in weight being about 1 gram a week. The maximum variation in length between the largest and smallest specimens was only 19 millimeters, while in other ponds variations in length as great as 111 millimeters were recorded.

These results are of great interest for comparison with those obtained at Fairport, since the methods employed were very different. The production of approximately 15,500 fingerlings per acre was no greater than has been obtained at Fairport, but the growth was more rapid, due, no doubt, to the heavy fertilization, which greatly exceeded anything which has been attempted in the ponds at that station.

The results also show that when sufficient numbers of Daphnia and insects are available bass can be reared successfully to a length of 3 inches or more without the use of forage fish. It is doubtful, however, if under ordinary conditions these animals can be raised in sufficient abundance through the summer to supply the needs of fingerling bass when the ponds are heavily stocked.

During the season of 1932 it is planned to carry on a series of experiments at Hackettstown to determine the relative value of Daphnia as the principal item of food throughout the summer as compared with forage minnows.

TROUT CULTURE

PITTSFORD STATION

As previously stated, the investigations relating to trout culture have been conducted at the experimental hatchery at Pittsford, Vt., which is operated under the direction of Russell F. Lord. These investigations include feeding experiments with both fingerling and yearling trout, selective breeding for the purpose of developing a superior strain of brook trout, and studies on trout diseases. Some field work is also being carried on, which includes a study of the natural food of trout throughout the year and the tagging of trout liberated in certain streams.

Construction work during the past year was confined to extensive repairs to the hatchery, which was in very bad condition, and minor repairs to several other buildings.

Feeding experiments.—As in previous years, fingerling brook trout from the same general stock of eggs were divided into lots each containing 1,500 fish. Each lot occupied a standard hatchery trough and was carried on an experimental diet from May 5 to September 3. Throughout the summer samples of fish were counted out and weighed at 2-week intervals.

Emphasis was laid on the further testing of dry products, which appear to offer the best possibilities as trout foods. A record was kept of the amount of food fed each lot of fish and its cost. In every case the fish were fed all they would eat without waste. No tests were made of straight meat diets, since sufficient data on these foods have already been secured. Beef liver was in most instances used in combination with the dry products, but with salmon eggs it was thought desirable to use other meats as well. Since beef liver

has been shown to give the best growth of any meat ordinarily used at hatcheries, it was fed to the control lots and was the only meat used straight.

It is interesting to find that the growth obtained with mixtures of meat and suitable dry products has each year approached more closely or even surpassed that obtained in the controls, and this year all the diets, with three exceptions, gave a greater growth than beef liver. The results show very clearly that there are now a number of dry products which, when fed in combination with fresh meat, are superior to a straight meat diet and cost considerably less. In other words, by the use of dry products it is possible to produce better fish for less money than can be produced on the standard hatchery diets in common use.

The outstanding feature of the feeding experiments for 1930 was the excellent growth and high color secured with dry salmon eggs. For this reason it was planned to give the salmon-egg meal a thorough test in the 1931 experiments and eight rations were made up with the meal incorporated in various proportions. In general the results of these experiments fully confirmed the conclusion reached in 1930—that in proper combinations salmon-egg meal makes the best trout food now available. As is to be expected, the best results were obtained with a mixture of salmon-egg meal and beef liver. The meal was used at 30 and 50 per cent levels, but the results show that 50 per cent of salmon eggs is too high for small fingerlings, although it can be safely used after the fish reach a length of 3 to 4 inches. With small fingerlings a considerable percentage of the meal is uneaten if more than 30 per cent is used in the mixture. In general the smaller the fish the greater the difficulty in feeding dry products, and in ordinary hatchery practice there is probably little to be gained in attempting to feed such products before the young trout are about 2 inches long.

The fish fed a mixture of sheep liver and salmon eggs made a slightly greater growth than those on beef liver mixture, but the mortality was higher. Data secured in previous experiments indicate that sheep liver is inferior to beef liver for brook trout when fed straight, but that in combination with certain dry products it gives much better results than when fed alone. Pig liver when used with salmon eggs was somewhat inferior to either beef or sheep liver, but owing to its lower cost it may be found advisable to use it with the larger fingerlings. For some reason a mixture of pork melts and salmon eggs proved a complete failure—the fish refuse to eat it and suffered such a heavy loss that the lot was discontinued early in July.

The superiority of salmon eggs rests not only on its ability to produce rapid growth but also on the fact that fish reared on this product show exceptional vigor and remarkably brilliant coloration. As might be expected, the latter is more marked in yearling than in fingerling fish, but is very noticeable at any age. It has also been found that an equally marked improvement in the color of rainbow and black-spotted trout follows the use of salmon eggs. This was especially noticeable in a lot of yearling rainbows, which showed a remarkable development of red and orange hues before the end of the summer.

Fish meals of various kinds have been used extensively in previous experiments and, on the whole, have given quite satisfactory results. This is especially true of the vacuum and steam-dried meals, which are superior to flame-dried and more uniform in quality. A haddock meal dried by a new process at low temperature gave excellent results in combination with beef liver. In fact, this mixture gave the best growth that has been obtained with any fish meal and was only slightly behind the salmon eggs in this respect. The mortality was also very low.

In previous years several attempts have been made to carry experimental lots through the summer on dry foods alone, but all such attempts have ended in failure. During 1931 another attempt was made to keep fingerling trout on a ration containing no fresh meat. These fish were fed a ration composed of 58 parts dextrin, 34 parts haddock meal, and 8 parts dry beef liver. The haddock meal and beef liver were dried by the special low-temperature process referred to above. The fish made a good growth, and for the first time in the history of these experiments it was possible to carry them through the summer without feeding any fresh meat. The mortality, however, was higher than normal, and it is not believed that the use of this ration for any length of time is to be recommended.

In addition to the experiments with fingerling trout, 20 lots of yearling brook trout were placed on experimental diets May 27 in small outdoor pools. These experiments were to have been continued through the summer, but owing to an unsuitable water supply this was found to be impossible. Unlike the hatchery troughs which are supplied with spring water, the only supply for these pools is from a neighboring brook. On account of exceptionally hot, dry weather early in the summer, the temperature of the brook rose to 72° F. This brought on an epidemic of furunculosis, which caused such a heavy mortality—in one lot reaching 86 per cent—that the experiments were discontinued on July 9.

Although these experiments with yearling brook trout were carried on for such a short time that the results are of little value, there is one aspect of the case which is of more than passing interest. During the previous summer there was some evidence that the inclusion of salmon eggs in the diet tended to make the fish less susceptible to furunculosis, and experience with the yearling trout strongly supports this conclusion. With one exception, the fish which showed the lowest mortality were on diets containing 50 per cent of salmon eggs. The single exception was a lot fed a mixture of equal parts salmon eggs and pig melts, in which the mortality was double that of any other lot receiving an equal amount of salmon eggs. As previously mentioned, this ration resulted in such heavy mortality with fingerling trout that it was discontinued early in the season. There can be no doubt that the lower mortality in the lots fed salmon eggs was due to the food, since in all other respects the experimental lots were treated alike.

Breeding experiments.—The work on selective breeding, which was started several years ago, has been continued along the same general lines as in previous years. Although it will be some time before the full possibilities of this work will be evident, each year shows a marked advance in the results attained. Progress would

have been even more rapid had it not been for the occurrence of furunculosis, which has caused serious losses among the selected fish. It is hoped that eventually it will be possible to develop a strain of trout more resistant to this disease than the average fish, but it is too early to predict how successful this attempt will be.

As in previous years, a number of selected fish were mated, and the progeny of each pair will be reared separately until it is determined if they possess any points of superiority. In addition to selecting such characters as fecundity, rapid growth, vigor, and resistance to disease, a special attempt is now being made to develop an early-spawning strain of fish. Such a strain would possess many advantages, especially in the extreme Northern States. During the fall of 1931 eggs were taken from 56 pairs of selected fish. Several of these showed an exceptionally high percentage of eyed eggs and one 4-year-old female yielded 2,557 eggs, 97 per cent of which eyed.

In this connection it is interesting to note that the average size of fingerling brook trout at the Pittsford station has increased each year from 1,630 grams per 1,000 fish in 1928 to 5,189 grams in 1931. Of course, this increase in size is partially due to the use of better rations, but that the greater part is due to improvement in stock as the result of selection is evident from a comparison of the experimental lots fed beef liver as shown in the following table:

Year	Weight in grams per 1,000 fish	Date when weighed
1928	2, 174	October 15.
1929	2, 893	September 24.
1930	3, 707	September 3.
1931	4, 421	September 3.

We can not, of course, hope to increase the size of trout fingerlings indefinitely, but there can be no question that by constant selection of the brood stock and by the use of improved foods it will be possible to produce trout of catchable size in a much shorter time than at present.

LEETOWN STATION

Construction work at the new experimental station at Leetown, W. Va., was started in the spring of 1931. This station is located on a tract of approximately 150 acres, watered by several springs with a combined minimum flow of over 2,000 gallons per minute. It is planned to operate this plant as a trout and pond station; but owing to lack of funds for developing the property, it will be impossible to do any pond-cultural work at present. Eventually, however, there will be between 75 and 100 acres of ponds devoted entirely to experimental work with warm-water fishes.

The main building, which is designed primarily for a trout hatchery, is now practically completed. This building is constructed of native limestone and is approximately 125 feet long by 40 feet wide. The middle section contains 60 standard hatching troughs on the ground floor, with offices, library, photographic room, and storage rooms on the second floor. Wings at each end of the building contain the laboratories and a public aquarium. Immediately in the rear of the main building is an old gristmill which has been remodeled to serve as a garage, carpenter shop, and meat room. A

short distance below the hatchery there is adequate space for the construction of a series of trout pools which will be used for experimental purposes and also for holding brood stock.

The trout work at this station will be devoted primarily to rainbow and brown trout, although brook trout will also be reared in considerable numbers. The Pittsford station, however, will continue to serve as headquarters for work with this species. As soon as sufficient brood fish have been reared it is planned to undertake selective breeding with rainbow and brown trout along the lines which have given such promising results with brook trout. It is also planned to undertake extensive feeding experiments, which will be continued throughout the year. In accordance with this policy approximately 500,000 rainbow, brown, Loch Leven, and brook trout have been hatched at Leetown, and a large percentage of the young fish will be held over the summer. This will insure an adequate supply of material for experimental work.

FISH DISEASES

Herring disease.—An investigation of a disease of the herring in the Gulf of Maine was begun early in 1931 and continued through the summer. This investigation was carried on in cooperation with the division of inspection of the Maine State Department of Agriculture, and the greater part of the expenses of the investigation was defrayed by the State.

During the winter and spring of 1931 a laboratory was maintained at Eastport, Me., where investigations were carried on by Dr. Frederic F. Fish and George E. Daniel. Later the laboratory was transferred to the Bureau of Fisheries station at Boothbay Harbor, Me., where much better facilities were available than at Eastport.

As a result of these investigations it was found that the disease in the herring is caused by a fungus of uncertain affinities known as *Ichthyosporidium* or *Ichthyophonus.* In addition to the herring (*Clupea harengus*), the parasite has been found on the flounder, alewife, and smelt. The herring, however, appears to be the natural host, infection in other species being apparently accidental.

The parasite occurs in all parts of the body, but is especially abundant in the heart, liver, and lateral-line muscles, and forms large, spherical, multinucleate cells, which are surrounded by a thick membrane. These spherical bodies or cysts occur in groups bound together by a heavy connective-tissue capsule.

Further development of the cysts takes place by the formation of a small circular opening in the wall, through which the protoplasm extends to form a short, branched hypha covered with a thin transparent membrane. The contents of the hypha break up into a number of discrete bodies, the structure of which is practically identical with that of the mother cyst. After the formation of the secondary cysts the tip of the hypha breaks open and the cysts are liberated. Such a process results in the liberation of a large number of bodies into the musculature of the fish, each of which can repeat the process by which it was produced.

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In some cases instead of forming hyphæ the contents of the cyst may divide into a number of daughter cysts, similar to those produced in hyphæ, by a process of endogenous budding. Later the cyst wall ruptures and the daughter cysts are set free in the surrounding tissues. Once the infection is established, the mode of diffusion of the parasite within an organ is not difficult to understand, but the means by which the infection spreads from one organ to another within the host is not so evident. It seems quite reasonable to assume that migration occurs through the circulatory systems, either lymph or blood, but so far it has been impossible to demonstrate such a process.

As a result of the development of the parasite within the host the surrounding tissues become necrotic, and in severe infections may disintegrate to form a puslike material which may be eliminated through an opening in the skin of the fish.

The development of the parasite is very slow, and it probably requires weeks or even months for it to become disseminated throughout the body of the host. In many cases the multiplication and dissemination of the parasite through the tissues appears to proceed gradually until every part of the body is affected and the host becomes so weakened that it eventually dies, or more probably is caught by one of its numerous enemies. In some instances even badly infected fish may completely recover and groups of parasites in various stages of resorption are by no means rare. The extent, however, to which normal recovery takes place is unknown at present.

Transmission of the parasite from host to host is probably effected by the heavy-walled cysts which are thrown off in large numbers through openings in the skin of infected fish. These cysts float about in the water and could readily be swallowed by another fish. There is no reason to believe that an intermediate host is involved in transmission of the infection. The evidence at hand indicates that the infection is much more prevalent among herring that have been in inshore waters for some time where there are better opportunities for the spread of the parasite. Apparently fish in offshore waters are usually relatively free from the disease.

Trout diseases.—Studies on furunculosis were continued by Doctor Davis at the Pittsford station. An investigation of an undescribed eye disease which was quite prevalent in several lots of fingerling trout was also begun. The first indication of this disease is a slight congestion of the blood vessels on the lower side of the eyeball. A little later irregular elevations appear on the cornea due to proliferation of epithelial cells. Eventually the entire cornea becomes thickened and opaque and more or less distended due to the accumulation of fluid between it and the iris. In some cases the cornea may disintegrate, allowing the fluid to escape into the surrounding water. In advanced stages of the disease the lens disintegrates and the entire eyeball becomes greatly shrunken.

Only the eyes are affected, and numerous instances were observed where the fish became totally blind but were apparently perfectly healthy in every other respect. The cause of the disease has not yet been determined.

It was found that the spread of the disease was checked by transferring the fish from hatchery troughs to outdoor raceways. After

the transfer the eyes of fish already affected continued to degenerate, but no new cases of the disease could be found.

Parasites of Great Lakes fishes.—During October and November, 1931, Dr. Frederic F. Fish made a preliminary survey of the extent of infestation with the larval stage of the cestode *Triaenophorus robustus* among fishes of the Great Lakes. This parasite was found to present a serious problem in the tullibees and whitefish of Lake of the Woods, the lake herring and whitefish of Rainy Lake, the lake herring of western Lake Superior, and the lake herring and chubs of the Green Bay region of Lake Michigan. The parasite was found to a lesser extent in the lake herring taken at Cheboygan, Saginaw Bay, and Marquette, Mich. Other fish, including the pike-perch, pike, pickerel, yellow perch, sauger, black sucker, redhorse sucker, bullhead, carp, crappie, and cisco, were examined in several localities and were found to be uniformly negative.

Lake Erie was found to be free from the parasite. Lake Ontario was not visited, but there is no reason to suppose that the parasite occurs there.

CALIFORNIA TROUT INVESTIGATIONS

Early in the year arrangements were made with the California Division of Fish and Game for a cooperative trout study in that State. In March a meeting of the members of the bureau's staff who are working on trout propagation was held in Washington, and an outline was made of those lines of investigation which promised to be of most help in maintaining the western game fishes under the constant increase in angling which has followed the extension of roads and the development of the automobile.

Three major lines of investigation were proposed:

(1) A study of the development of a domestic brood stock as a source of eggs.

(2) Investigation of the problems involved in raising larger fish for planting.

(3) The development of a stocking policy through stream surveys.

Active work on this program was started in May. This preliminary work has included a survey of certain streams with a view to selecting those which are suitable for experimental work. In the course of this work streams have been studied in the four geographical groups into which the streams of the State may be divided, viz, the streams of the eastern slope of the Sierras, of the western slope of the Sierras, of southern California, and of the Coast Range from Monterey north to the Oregon line.

Data have been gathered also regarding the development of selected brood stock as a source of eggs. This has included a study of the present brood stock in the State and the characteristics of the wild stock from which eggs are now derived.

It was not possible to start selected brood stocks during the present season, as no sites were available for holding such fish, but plans have now been formulated which will make it possible to carry on this work during the coming year. There is a particularly pressing need for the development of a source of brown-trout eggs in southern California, and it is now planned to use for this work certain storage reservoirs which are not subject to great fluctuations in level.

The development of a brood stock and the raising of larger fish for planting are both largely dependent upon the availability of suitable water. This problem is particularly acute in California, where practically all the water at low elevations is stored or diverted for irrigation.

An excellent site for this type of work has been developed at Hot Creek, in Mono County, which is on the eastern slope of the Sierra Nevada Mountains. Warm springs arise along the course of this stream which have a constant temperature of 60° F. and a flow of about 30 second-feet. The gravel bed of the stream is covered with water cress and other aquatic plants. Fish food is abundant in the form of the amphipod *Gammarus ramellus*, which is present in numbers up to 1,000 per square foot of stream bottom. The terrain is such that ponds can be constructed and maintained at low cost. During the latter part of the year two experimental ponds were constructed at this place. Due, however, to a heavy fall of snow in December, it was impossible to stock these ponds during the present year. There is sufficient water at Hot Creek to allow of the establishment of both brood stock and fingerling ponds.

Two streams have been selected for the study of the life history of the steelhead, including the study of the migratory movements of the young fish through marking and by monthly sampling in the upper parts of the streams and in the lagoons. This work has been somewhat hampered by exceptionally heavy rainfall and the consequent flooding of the streams, but work is also being done on the migration, growth rate, and egg production of the adult fish through tagging.

LIMNOLOGICAL INVESTIGATIONS IN THE NATIONAL PARKS AND FORESTS

Following conferences early in the year 1931 the Bureau of Fisheries announced recognition of its responsibility in stocking the public domain with food and game fishes, and plans were made for active cooperation with the Forest and Park Services to fulfill that responsibility in a competent manner. As its specific duties the bureau proposed to undertake scientific surveys of forest and park waters as a basis for drafting a national program of fish planting, and plans were made for the Forest and Park Services to cooperate with the bureau in the planting of fish in accordance with an orderly plan of stocking. To carry this out the bureau proposed to organize in each of the national-forest areas of the United States investigations under a competent biologist who should conduct and supervise stream and lake surveys in the waters of the public domain, and who should develop therefrom a rational policy of stocking such waters with fish.

A preliminary survey of the lakes and streams of Wasatch National Forest in Utah was conducted during the summer of 1930, and in June, 1931, a permanent investigator of the bureau, Dr. A. S. Hazzard, was placed in charge of stream surveys in the intermountain region.

The primary purpose of these studies is to collect basic physical, chemical, and biological data on the lakes and streams of these areas and to interpret these data in the form of systematic stocking pro-

grams to meet the increasing demand for game fish in public waters. Along with this immediately practical program, fundamental studies concerning production of fish food and fish in unit areas of water of different types are being planned. The ecology and distribution of the little-known fishes of the Rocky Mountain region are being investigated as a part of the survey work in these areas.

WASATCH FOREST INVESTIGATION

The Wasatch forest has been designated as an experimental area in which fish-cultural experiment and stocking programs can be carried out to the ultimate benefit of the entire Rocky Mountain region. As a basis for this work, a preliminary biological survey of representative lakes and streams was undertaken. Collection of the field data during the seasons of 1930 and 1931 was made by Prof. Vasco M. Tanner, of Brigham Young University, who, with a staff of four assistants, spent the months of July, August, and September in a reconnaissance survey of the representative lakes and streams of this area. During the first season 86 lakes and a few streams were examined. The summer of 1931 was devoted primarily to a study of the principal stream systems, although some lake study was also carried out. A total of 107 lakes and 34 stream systems were examined during the two seasons.

Lake studies.—The majority of the lakes of the Wasatch Forest lie at elevations from 9,500 to 11,500 feet. The growing season for most forms of aquatic life, including the trout, probably does not exceed four months, judging by the fact that the ice does not disappear from the majority of the lakes until June and begins to form early in October.

Although locally termed as lakes, these bodies of water are all relatively small, varying in size from 1 to 160 acres and having a total area of only 1,715 acres. They are for the most part shallow lakes of glacial origin.

The entire drainage area being in pre-Cambrian quartzite, the water is extremely soft, varying in pH from 4.9 to 5.5, with a bicarbonate content of from 5.5 to 15.2 parts per million. Dissolved oxygen of the surface water varies from 6.2 to 8.9.

The lakes studied, classified according to the type of shore, are: Rocky, moorland or boggy, and reservoir lakes. Although intermediates between the first two classes are common, the latter type, though a man-made class, is quite distinct in chemistry and biota. The first class is characterized by rocky shores and bottom; shallow, clear water rich in oxygen and exceedingly low in carbonates and a sparse fauna and flora. The boggy-shore type is found in stream valleys, usually surrounded by boggy meadows. These lakes have mucky bottoms, and the oxygen tends to be reduced in the deeper waters due to the decomposition of organic matter and to the small size of tributary streams. A fair abundance of a few species of organisms makes up the food supply. The reservoir type is usually the result of damming originally boggy-shore lakes to increase their storage area for irrigation purposes. Great fluctuation in water level occurs in contrast to the fairly constant area of the other types. Food of the bottom and plankton types is quite abundant at low-water stages, probably due to concentration with decrease in area.

In general, all of these lakes contain a limited supply of food, probably due to the short growing season and the low lime content of the waters. Some of the rock-rimmed lakelets at the higher altitudes were considered unsuitable for trout because of the extremely limited food supply. The boggy-shore lakes were held to be unsuitable if tributary streams were lacking, and the process of filling had advanced too far. However, a good proportion of these types, as well as the type intermediate between them, should provide for a limited number of trout. The reservoir type is considered suitable for a moderate number, depending upon the level to which the waters are reduced.

The only fish native to the region and naturally present in lakes not separated by impassable falls from lower waters is the cutthroat trout, *Salmo pleuriticus* Cope. No forage fish such as minnows and whitefish were observed in any of the lakes, and their introduction is considered as a possible means of improving production. Many of the lakes were formerly barren of all fish life. Rainbow, eastern brook, and Yellowstone cutthroat have been introduced into some of these lakes, and where the plantings were moderate have made good growth. Food studies of 153 specimens of trout of lakes show no noticeable difference in diet among the species represented, the food taken by native cutthroat, eastern brook, and rainbow consisting of 25 per cent terrestrial and 75 per cent aquatic organisms. Midge larvæ, pupæ, and plankton crustacea comprised the bulk of the aquatic food; ants, the bulk of the terrestrial food.

Stream studies.—Five drainage systems are located in the Wasatch Forest: Provo, Weber, Bear, and Duchesne Rivers and Rock Creek. The headwaters of these streams are very rapid and the pools are narrow, shallow, and infrequent. The pH varies from 5.1 to 5.6 and the bicarbonate content from 7.3 to 12.6 parts per million; food organisms are extremely scarce. In their lower reaches, near the forest boundaries the gradient becomes less steep, the pools improve in type and abundance, and the fish food undergoes a marked increase. The latter appears to be associated with a marked change in the solution content of the waters due to the occurrence of limestone outcrops within the drainage area at the lower elevations. The bicarbonate content of the streams below 8,500 feet elevation varies from 18.3 to 56.7 parts per million.

Stomach examinations of stream trout showed a larger percentage of terrestrial food in the case of cutthroat trout and eastern brook trout than was consumed by these species in the lakes. As in the case of lake fish, ants formed the bulk of the terrestrial food. Caddis larvæ made up 35 per cent of the food of stream trout, with mayflies, midges, and stoneflies next in order of importance in the aquatic food list. One sculpin and one young trout had been taken by these fish.

The principal conclusions to be drawn from the stream studies is that stocking of trout should be largely confined to the lower waters where food and pool conditions are suitable, but detailed tables of the species, sizes, and numbers of fish and the frequencies of planting in the various waters have been prepared for the use of the fish-cultural staff.

TETON NATIONAL PARK INVESTIGATION

The biological survey of the waters of the Grand Teton National Park is the first of a series planned for the national parks in order that systematic stocking plans for these waters may be devised.

Field work was conducted from July 20 to September 20. An exchange of personnel was effected between the members of the Wasatch and Teton survey parties for a part of the season in order that the work in these areas might be better coordinated.

Six lakes, from 60 to 1,360 acres, with a total area of 3,443 acres, afford the principal fishing in this park. The streams within the park are too small and precipitous to afford much angling, although they are extremely important in furnishing the only successful spawning grounds for the cutthroat trout of the lakes.

Studies of aquatic plants, plankton, littoral, and benthic organisms were made. Studies of temperature, depth, type of bottom, and clemical relations were undertaken. The fish population was investigated, and collections of fish stomachs and scale data secured from 145 specimens of cutthroat trout. A preliminary survey of Jackson Lake was also made which included extensive soundings and fish collections.

A systematic stocking plan is being formulated for these waters based upon the data secured during this survey.

With two exceptions, the lakes of this area were found to contain considerable water over 50 feet in depth. Abundance of oxygen and small amounts of carbon dioxide were found in all but one of these lakes. The large volume of the cold tributary streams and the scarcity of organic material are responsible for this condition. The waters of the park are acid for the most part and contain small quantities of bicarbonates, with the exception of the southernmost lakes and streams which drain some areas of limestone formation in contrast to the igneous and metamorphic rock which make up the drainage areas of the more northern waters. A marked superiority in the quantity of aquatic fauna and flora was noted in these more southern waters.

The present reduction in the trout population in the Teton lakes is believed to be due to the increase in angling, lack of sufficient artificial plantings, and to the scarcity of suitable spawning beds for the cutthroat trout. Gill netting, seining, and observation failed to show the presence of young trout, smaller than 7 inches in the lakes, although fry and fingerlings were common in the inlets and outlets of the lakes. Impassable falls near the lakes limit the spawning areas to a few hundred yards in most cases. Consistent stocking should show a marked improvement in the angling in these lakes in the near future.

Studies of 109 cutthroat trout of lakes and 36 of streams show a marked difference in the food habits of this species, depending upon size and environment. Fish are unimportant in the diet of stream trout of the sizes taken, due in part to the scarcity of this type of food here. Aquatic insects formed approximately 75 per cent of the food; terrestrial insects 25 per cent. In lake fish aquatic insects formed 3 per cent by volume, terrestrial insects 7 per cent, plankton crustacea 10 per cent, and fish 60 per cent, indigestible and unidentified material contributing the balance. Fish formed the largest

item in the diet of the lake fish after they had attained a size of about 12 inches. Up to this size plankton crustacea formed about 25 per cent of the food. From this it is evident that the larger cutthroat trout consume considerable numbers of forage fish where they are available. Stomach examinations of 46 fry of this species showed a great variety of diet, with the larvæ of Chironomous forming the most important item.

OYSTER INVESTIGATIONS

During 1930 investigations relative to various phases of oyster culture were carried out along the Atlantic and the Pacific coasts, the staff of the investigators being more or less evenly distributed in different oyster-producing sections. In New England waters the headquarters for oyster investigation remained, as in previous years, at the Fisheries Laboratory at Woods Hole, where work on physiology of spawning has been continued. Cold Spring Harbor Biological Station, on Long Island, was selected as a suitable place for an experimental study of the control of starfish. The Beaufort (N. C.) laboratory served as the headquarters for South Atlantic investigations, which were greatly expanded during the last year and extended from North Carolina to Florida. On the Pacific coast a study of the life history and cultivation of the west coast oyster, *Ostrea lurida*, was continued. Thanks to the cooperation with the Washington State Department of Fisheries and Game, a small but well-equipped laboratory located in the center of the oyster industry near Olympia was made available for the bureau's investigators. In cooperation with the State authorities of Oregon and California, a survey of local oyster bottoms and experiments on oyster culture were made.

PHYSIOLOGY OF SPAWNING

A study of factors that control spawning is of paramount importance for the successful cultivation of oysters.

The results of the large number of experiments with *O. virginica* carried out by Dr. P. S. Galtsoff from 1927 to 1929 show that no spawning occurs below 20° C., whereas the same specimen can be induced by sperm to spawn as soon as the temperature has been brought above 20°. In a few instances it has been noticed that oysters spawned at 27.5° without being stimulated by sperm. Inasmuch as in those cases unfiltered water was used, the possibility of its contamination with sperm was not excluded. In the experiments with *O. gigas* it has been found that a ripe female can be induced to spawn by a temperature of 30° C. The question naturally arises whether the same results could not be obtained with the other species. During the summer of 1931 experiments were carried out at Woods Hole with ripe *O. virginica* which were kept in aquaria at a temperature of about 20°. To avoid possible contamination the water used in the experiments was filtered through a layer of asbestos about three-quarters of an inch thick. The results of the experiments indicate without any doubt that ripe females can be induced to spawn by placing them in water having a temperature from 24.5° to 30° C. At 31° the females usually close their valves and remain closed until the temperature drops to 30° or 29° C.

The latent periods of spawning reactions—that is, the time elapsed from the moment the oyster was exposed to a given temperature until the beginning of spawning—varies from 20 to 257 minutes and apparently is not correlated with the temperature, the quickness of the response probably depending on the condition of the organism itself.

The fact that the females can be stimulated by a temperature of 24.5° C. or higher suggested the possibility that similar effects might be obtained by a longer exposure to temperatures between 20° and 24.5° C. The results of a large number of experiments, of which only three will be described here, show that this is very doubtful. On July 10, three ripe females were taken from the tank, in which the temperature during the previous week fluctuated between 18.5° and 19.5° C. and placed in an aquarium filled with filtered sea water. The temperature was kept at 22.6° but occasionally rose to 23.4°. The shell movement of each oyster was recorded on the kymograph. The first oyster was kept for 5 hours and 22 minutes, the second for 29 hours and 53 minutes, and the third one for 73 hours and 13 minutes. The water in the aquaria in which the second and third oysters were kept was changed twice a day. None of the oysters spawned during that time, but each of them spawned after sperm were added to the water, the latent periods being 16, 24, and 15 minutes, respectively.

It is interesting to note that in both cases of stimulation, either by the temperature or by the sperm, the reaction is alike and is characterized by a series of rhythmical contractions of the adductor muscle and of the mantle. From that an inference can be made that both factors release some mechanism in the organism of the female which in turn stimulates the muscle and causes the discharge of eggs from the ovary. In this respect the reaction is not specific. It is, however, specific in the sense that sperm of other mollusks (Mya, Mytilus) fail to induce spawning of the oyster. No positive results were obtained also when the sperm of *O. cucullata* was added to the female of *O. virginica* and vice versa.

From a biological point of view stimulation of spawning either by the temperature or by the sperm-and-egg suspension is of great interest. It provides a mechanism which insures successful propagation of the species. Should the temperature of the sea water fail to reach the effective point which would induce shedding of eggs by the females, still the spawning of the latter could be provoked by the sperm discharge of the males, which are more susceptible to the increase in temperature. In most of the cases observed by Doctor Galtsoff, when several oysters were kept together the males spawned first and induced the shedding of eggs by the females. The process, once started, spreads by mutual stimulation of the two sexes throughout the whole oyster bed and results in simultaneous spawning of the oyster population.

SOUTH ATLANTIC OYSTER STUDIES

Investigations and experiments of a practical and scientific nature are being conducted from North Carolina to Florida under the supervision of Dr. H. F. Prytherch, director of the Beaufort (N. C.) laboratory, which serves as the headquarters for this work. In

cooperation with the State shellfish commissions and various oyster producers, small experimental oyster farms have been established in each State for the purpose of determining and demonstrating the most efficient methods for oyster culture in each particular region. The production of oysters for both the canning and raw trades are important industries in this region, and the industry is cooperating in this work with a view to improving the size, quality, and quantity of oysters grown for these purposes.

In this section a greater industry and market for raw oysters can be developed not only by increased production of large oysters but especially through improvement in the methods of opening oysters and their preparation for market or shipment. The latter is particularly important in this warm climate and consequently experiments along this line have been undertaken at the Beaufort laboratory, which, as described later, show excellent possibilities for supplying the market with oyster meats in a fresh sanitary condition.

The results of the experiments in oyster farming in the South Atlantic region are described briefly according to the States in which these operations were conducted.

Relation of copper content of water to oyster setting in the South Atlantic.—Previous studies in the North have shown that the copper content and salinity of the water are the chief factors controlling setting and the production of seed oysters. Further investigations show that a similar relationship also exists in North Carolina, South Carolina, and Georgia. Chemical analyses of the water in these localities showed the presence of copper in amounts varying from 0.05 to 0.4 milligram per liter. The heaviest setting was found to occur at the surface of the water during the stage of tide when the copper content was highest. Partition collectors placed at such tidal levels gathered from 1,200 to 3,500 seed oysters per collector.

In southern waters the reproduction and setting of oysters is so abundant as to constitute the greatest handicap to their cultivation. Usually there are two crops of seed each summer, which fasten chiefly upon the adult oysters and so seriously interfere with their feeding and growth as to kill them or produce an inferior oyster. Consequently the studies on setting are being continued in the hope of finding a practical means for controlling or preventing the heavy setting of oysters in certain areas. While copper in minute amounts is beneficial for setting, it also true that slightly higher concentrations of this metal are decidedly toxic to the oyster larvæ. Experiments are in progress to determine the practicability of using copper salts or other toxic substances to prevent the overcrowding and inferior growth of oysters in southern waters as a result of heavy setting.

Improved methods in the preparation of oysters for market or shipment.—The shucking of oysters and their preparation for market are costly operations and of considerable importance in determining whether the consumer will receive this valuable sea food in a first-class physical, chemical, and sanitary condition. Experiments conducted at the Beaufort laboratory by Drs. Vera Koehring and H. F. Prytherch give promise of developing an inexpensive and efficient method of removing oyster meats from the shell more quickly, with less difficulty and labor, and particularly with little

or no injury to the oyster tissues. The method may be of further value from a sanitary standpoint, as the medium employed inhibits the growth of spoilage organisms and leaves the meats in better condition for shipment.

In removing the meats by this method the oyster muscle is "put to sleep" or narcotized. Relaxation of the muscle occurs, and the valves of the shell are automatically pulled apart by the pressure of the hinge so that an oyster knife can be easily inserted and the muscle severed from the shell with less injury to the meat than by present methods. The narcotization of oysters is accomplished by the use of a small amount of certain mineral and organic acids in combination, which in experimental procedure costs less than 10 cents per thousand oysters. Oysters may be completely narcotized or caused to gape within a period of six hours, and can be kept without injury in this condition for a considerable length of time. In the experiments conducted thus far the number of completely narcotized oysters in each lot treated has varied from 60 to 90 per cent. In this connection the type and concentration of the chemicals employed are important and further studies are in progress to improve the technique of administering the reagents and test the method on a small commercial scale.

An important feature of this process is that it is not injurious to the oysters, as they fully recover when returned to fresh sea water and may be treated several times in this manner without deleterious effects. The chemicals employed do not cause shrinkage or volume losses of the meat nor impair their food and market value. Narcosis is obtained by using higher concentrations of chemical substances which normally occur in the body and environment of the oyster. Various inorganic and organic reagents are being tested from a practical standpoint to determine their relative efficiency and value for opening oysters. Those in use at present appear to largely disinfect the oyster meats in the process of opening and keep them fresh, firm, and in excellent condition, free from decomposition, for a long period after treatment. The bacteriological phases of the narcotization process will be studied in greater detail later in respect to the purification of oysters both shucked and in the shell. It appears likely that the principles employed in opening oysters by chemical means can likewise be used to improve the keeping qualities of oyster meats in shipment. In the southern climate particularly such improvement is needed and will greatly aid the marketing of oysters and development of the industry.

Oyster investigations in North Carolina.—During the past summer a general survey has been made of the oyster-producing areas in the vicinity of the United States Fisheries Laboratory at Beaufort, N. C., in order to determine the most suitable methods for the development of oyster culture in this region. Experiments and chemical studies dealing with the setting of oysters and the collection of seed have been made in cooperation with Capt. John A. Nelson, State fishery commissioner.

Various types of collectors for gathering seed oysters have been tested on experimental grounds in Core Creek, Newport River, Oyster Creek, and at the United States Fisheries station at Beaufort. In Core Creek a very good crop of seed oysters was obtained on cement-

coated tubes and partitions that were planted there on July 23. The partitions were planted just above low-water mark on a natural oyster bed and gathered from approximately 100 to 500 seed oysters per collector. The cement-coated tubes are a new type of spat collector that was developed here during the past summer for gathering set on soft mud bottoms where shells and partitions can not be used. Tubes 2 feet in length and 1½ inches in diameter proved to be the most satisfactory size and collected from 200 to 300 spat each. They were planted vertically in the soft mud bottom surrounding the oyster reefs and were most heavily covered with spat when set out at low-water level.

The heaviest setting of oysters in this region occurs in a narrow 1-foot zone just above low-water mark, and has been found to be due to the higher copper content of the water at this stage of tide. Chemical analysis of the water showed the presence of copper in concentrations of 0.3 to 0.4 milligram per liter and a salinity of 15 to 18 parts per thousand during the tidal period when the setting of oysters was most pronounced. At other stages of tide when setting did not occur the salinity of the water was high (30 to 33 parts per thousand) and the copper content less than 0.05 milligram per liter. Therefore, in planting seed collectors of any kind in this region it is obvious that particular care must be taken to select the zone in which heaviest setting occurs.

A study of oyster distribution along the shores of Core Creek and canal revealed a new kind of brush that can be utilized for gathering seed oysters on the adjacent mud bottoms. The branches and trunk of the myrtle were found to be excellent for this purpose and were densely covered with well-shaped, rapid-growing oysters of different ages. Experiments with this brush will be made here during the coming year.

In Oyster Creek partition collectors were planted on June 17, by Inspector Robert L. Willis, of the State fisheries department. They were elevated a few inches above the bottom on stakes and gathered a light set of approximately 200 seed per partition. Setting in this locality is rarely heavy, which makes it a particularly valuable area for the growing and maturing of large, well-shaped oysters for market.

The partitions and tubes planted on Cross Rock in Newport River likewise collected during the latter part of July a light set similar to that observed on the shells covering this oyster reef. This bed produces a good grade of oyster, but is not as favorable a location for seed collection, as the near-by coon oyster areas.

At the fisheries laboratory the setting of oysters has been more or less continuous from the first week in June up until the first of October. Two plantings of partitions were made and collected a crop of seed oysters ranging from 200 to 1,500 per collector. The heaviest setting was found on partitions planted from low-water mark to 2 feet above and is governed by the lower salinity and higher copper content of the water during this stage of tide. Chemical analysis showed that at such times copper was present in concentrations of 0.15 to 0.20 milligram per liter and served as a pronounced stimulus for the setting of the oyster larvæ.

In summarizing these studies it is evident that partitions, tubes, and brush are commercially practicable as devices for collecting seed oysters in North Carolina waters. When planted on suitable bottoms they can be utilized for gathering an almost unlimited supply of seed of fine quality, which is the first essential requirement in successful oyster culture. The second requirement is the transplantation of the seed to selected growing and maturing bottoms where setting does not occur and interfere with the development of single, well-shaped oysters. Studies of this second phase of the problem are just being started through a series of cruises with the new State boat and United States Fisheries craft to the chief oyster-producing areas in North Carolina. In various localities suitable oyster-growing bottoms will be selected and used as experimental seed-planting grounds.

Oyster investigations in South Carolina.—Preliminary studies have been made at three representative oyster-producing areas in South Carolina for the purpose of determining the most suitable methods for the development of oyster culture in this region. These studies have been made in cooperation with J. M. Witsell, chairman of the South Carolina Board of Fisheries. Various experiments and chemical studies dealing with the setting of oysters and the collection of seed were carried out at Folly Island, Beaufort, and Bluffton. At these stations two definite crops of seed oysters were obtained, the first occurring from the 5th to the 20th of June and the second during the last two weeks in September. By the 20th of October the first crop of seed had attained an average length of 1½ inches, while the fall crop measured on the average only one-fourth of an inch in length. The June set was fairly heavy, especially at the State experiment station at Folly River, where the partition collectors gathered from 2,000 to 5,000 seeds per collector. The September set was much lighter in this locality and ranged from 500 to 1,200 seeds per collector.

At the Folly River station the partition collectors and oak poles planted showed that setting occurs in a zone extending from low-water mark to 3 feet above, but is decidedly heaviest in the 1-foot zone above low-water level. Chemical analyses showed that the copper content of the water increased with the ebbing of the tide and was highest (0.35 part of copper per million) when the tide reached low-water mark. Copper stimulates greatly the attachment of the oyster and was found in this locality to have a direct bearing on the abundance of oysters at different tidal levels.

Similar results were obtained in the experiments carried out at Beaufort, S. C., in cooperation with Capt. John L. Wall, of the Maggioni Oyster Co. and at Bluffton in cooperation with the H. O. Lowden Oyster Co. It was found that the planting of shells or artificial spat collectors on the tidal flats can be more efficiently carried out if particular attention is paid to the time of setting and the selection of tidal levels where seed oysters attach in greatest abundance. Since sedimentation is unusually heavy in this region and may in a short time cover seed collectors with a layer of mud, it is obvious that such devices must be planted just prior to the time of setting to be most effective. Experiments with oak poles and brush show that they are very satisfactory under these conditions for

gathering seed oysters if planted vertically, as the surface remains clean and offers the oysters better conditions for feeding and growth than is afforded by old shells. The development of oyster culture by brush and pole methods, similar to those employed in Japan and Australia, appears to be the most practical means for utilizing the extensive mud flats in South Carolina and improving the quality of oysters grown in these waters. Experiments on a small commercial scale will be carried on along this line during the coming year.

Oyster investigations in Georgia.—At Turtle River experiments in oyster farming were conducted in cooperation with T. Q. Fleming, of Brunswick, and the Georgia State Board of Game and Fish. Two phases of modern oyster culture were successfully demonstrated through the collection of seed oysters on brush and shells and the transplantation of year-old seed oysters to hard-clay bottoms, where conditions proved favorable for growth and the prevention of overcrowding by heaving setting. During 1931 the spawning and setting of oysters were heaviest in this locality during the period from the middle of May to the middle of June. A very light set of little importance was also obtained the early part of October. Oak poles and brush were planted on the tidal flats and gathered a good crop of seed oysters, thus demonstrating the value of such operations for utilizing the extensive barren mud bottoms in this region. Several hundred bushels of year-old seed from the overcrowded coon oyster reefs were transplanted to deep-water, hard-bottom areas and have shown rapid growth and considerable improvement in shape of the shell over those left on the natural beds. Studies of the temperature, salinity, hydrogen-ion concentration and copper content of the water and their relation to the setting and distribution of oysters in the Turtle River region were made. An examination of many of the natural oyster beds in Georgia showed considerable evidence of depletion from overfishing and the necessity of rehabilitating these beds and adjacent areas by increased planting of shells and brush seed collectors.

CONTROL OF STARFISH

Starfish investigations carried on by Louise Palmer were conducted with the view of finding an efficient method of combating this dangerous enemy of the oyster.

The common starfish, *Asterias forbesii*, is found along the Atlantic coast from Maine to the Gulf of Mexico, and is the only species common from Cape Cod to New York, an area which is the center of the largest cultivated oyster grounds in the United States.

The problem of starfish control from a practical standpoint resolves itself into the following points:

(1) The present mechanical method of controlling starfish is quite inadequate in decreasing the population to any noticeable degree and is very expensive.

(2) Overhandling and manipulation of oysters results in stunting the growth or even killing individuals.

(3) Great, or perhaps the greatest, damage is done by young, almost microscopic starfish on the spat, for which loss no method of control has been practiced.

Although starfish mops have been used for more than 50 years, there seems to be no diminution in the number of starfish, and they are as serious pests to-day as they were when control was first advocated. A most wasteful result of mechanical control is the injury to the oyster. Aside from the fact that starfish are continuously eating oysters, the mops chains and dredges are continuously breaking off the new shell growth faster than it can be deposited. Such a practice continued over a period of time results in a stunted oyster which requires another year of growth before marketing.

Another phase of the problem is the actual number of shellfish consumed by the starfish. Young starfish 2 or 3 days old can open and digest a 3 or 4 day old spat in a little over 20 minutes. In 11 hours after an adult starfish crawled into a two-year-old oyster it left the shell empty and absolutely clean. On July 21, 1931, 35 starfish, with an arm length between 4 and 7 centimeters were placed in a wooden float in Cold Spring Harbor, and clusters of year-old oysters provided as food. Twelve days later 46 oysters had been eaten and after 30 days 79 were eaten and the average increase in starfish arm length was 0.7 centimeter. Under population conditions as they exist in some seriously infested areas, starfish could completely wipe out an oyster crop if left undisturbed. Because of the inadequacy of the present mechanical methods of combating starfish, attempts were made to control them by chemical means.

The chemistry of sea water is, however, so complicated, its living organisms so varied and important to man, that it is indeed presumptious to propose the using of a poisonous chemical in the water as a means of control. Studies have been made on cases of unusual mortality of organisms or of their destruction due to pollution by industrial wastes, but little or no attempt has been made to artificially change the sea water in order to limit certain forms.

Such a procedure meets with seemingly and perhaps actually insurmountable difficulties. In the first place, any substance which can kill one form is poisonous in a greater or less degree to nearly all other living organisms. Their only hope of escape would be a more effective protective mechanism. Starfish, having an exposed respiratory and circulatory system and a relatively slow locomotion, are less able to protect themselves than oysters, crustacea, or fast-swimming fish.

Many chemicals were tried, but copper sulphate seemed to be the only substance effective in small amounts and at the same time worthy of practical consideration. During the summer of 1931, at the laboratories of the Long Island Biological Association, experiments were performed to determine the effect of that salt on starfish, oysters, and other marine forms.

Experiments with adult starfish show that the time necessary to kill the organisms varies in relation to concentration from 2½ hours (10 parts of $CuSO_4$ per million) to 3 minutes (1,000 parts $CuSO_4$ per million). Starfishes of various age show remarkable difference in susceptibility, the small individuals being affected in a shorter time than the larger ones. For instance, starfish of less than 1 centimeter will be killed by the concentration of 10 parts per million in 5 minutes, but those more than 5 centimeters long remain alive after nearly 2 hours' exposure.

In order to determine the effect of the various environmental factors on the toxicity of copper sulphate, temperature, salinity, and hydrogen-ion concentration were controlled or varied with interesting results. A series of experiments where starfish 3 to 7 centimeters in size were exposed to 500 parts per million of $CuSO_4$, at temperatures ranging from 10° to 35° C., show that exposure necessary to kill decreases from 8 minutes at 10° C. to 1½ minutes at 35° C.

A number of experiments were run testing the effect of pH within the normal range, 7.5 to 8.4. There was a slight tendency for the water with originally lower pH to be more toxic in a given concentration. Individual susceptibility is so varied and the differences so small that the results were quite inconclusive. However, as soon as the pH were artificially lowered below 7 the toxicity became much more pronounced. Whether deaths were due to the copper ion alone could not be determined, for the animals die upon prolonged exposure to water high in hydrogen ions. Copper sulphate lowers the pH of sea water due to its carrying out in the precipitate carbonate and hydroxyl ions. When copper salts are added to acidified sea water no precipitation occurs, and although the toxicity is greatly increased we are dealing with an entirely different phenomena.

The above factors are of considerable importance when practical application of the salt is considered. There is variation in salinity and hydrogen-ion concentration during each tidal cycle. Temperature varies with the seasons, depth of water, river discharge, and solar radiation. A correlation of these factors, together with a lethal concentration of the copper salt and a knowledge of the habits of the starfish, may produce a workable method for control.

Experiments using copper sulphate on the oyster beds.—Several methods were attempted in order to see whether it would be practicable to use copper sulphate as a killing agent for starfish on the beds. The first question was concerned with the method of application. The following experiments were tried, and the results are listed under each discussion.

Experiment No. 1 was conducted on the Bluepoints Oyster Co. grounds at Centerport, Long Island, August 4 and 5, 1931. One acre, 6 to 10 feet deep, 300 feet from low-tide line, was chosen for the experiment. A small hand dredge dragged for one minute caught in three hauls an average of 13 starfish 6 to 8 centimeters in size. A concentrated solution of copper sulphate in acidified sea water was prepared by adding 80 pounds of copper sulphate to a barrel holding 7 cubic feet of water. Using a hose, this solution was slowly pumped over the bottom for 20 minutes at slack low tide. The entire acre was covered by circles of the boat. The initial copper content of the water was 0.05 part per million and the pH 7.8. Immediately after the treatment there was 0.6 part per million of copper and a pH of 7.2 at the bottom. The next day there were virtually no starfish on that area, in eight dredges there were three live starfish and no dead ones. Oysters, scallops, and crustacea showed no ill effects. The water, pH, and copper content of the water were normal. Some of the tops of the sea weed and grass were killed, but the roots were unaffected and the grass survived.

Experiment No. 2 was conducted on the Andrew Radel Oyster Co. grounds at Oyster Bay, L. I., August 16 and 17, 1931. The area

chosen was offshore and averaged 16 feet deep. The starfish were small, ranging in size from 3 to 6 centimeters, and were very numerous. The same type of experiment as before was tried, except that a 12-foot 1¼-inch brass pipe was used to form horizontal bar of the T and the T connected by a large hose to the bilge pump of the steam boat. One hundred fifteen gallons of solution containing 100 pounds of copper sulphate and 75 pounds of nitre cake were placed in vats on the deck. The nitre cake is a crude sodium acid sulphate containing a high percentage of sulphuric acid and serves to make the solution more acid, and consequently retards the reaction of the copper with the sea water.

The solution was pumped out at slack low tide on August 17, along a straight line of 500 feet. Twelve minutes pumping emptied the vat. The original pH was 7.8 and the copper content 0.1 part per million. Immediately following the treatment the pH value had dropped to 7.2, but the copper content showed only 0.7 part per million. Next day there were practically no ill effects noticed on the starfish. In three dredges bringing up 33 starfish after a minute's hauling there were only 4 dead ones. The pH and copper content had returned to normal. Better results were obtained in the experiments on grounds of the Beacon Oyster Co., at Wickford, R. I.

A summary of the results of numerous experiments brings out the following points:

(1) Copper sulphate in no case killed more than 10 per cent of the starfish.

(2) Application as a solution is to elaborate in manipulation and no more effective than crystals.

(3) The most effective application consists in scattering crystals of copper sulphate at slack low water, preferably at neap tide.

(4) Starfish reaction to the presence of copper sulphate is one of avoiding the treated area.

(5) The use of paper bags filled with crystals presents a more accurate and economical method of application.

(6) Only in one case were there indications of death of the oysters. Periodic treatment did not seem to affect the food supply to such an extent that the oysters were harmed.

Because of the difficulties encountered in killing adult starfishes by copper-sulphate treatment, it is expected that the solution of the problem can be found in the control of propagation of starfishes rather than in destroying the adults.

PACIFIC COAST OYSTER STUDIES

At the Hopkins Marine Station, Pacific Grove, Calif., experiments were made by Dr. A. E. Hopkins during three months on the sensitivity of the oyster to salts, most of which normally occur in sea water. The chemical sense of the oyster is highly developed, as shown by the following threshold concentrations: Potassium sulphate, M/640; potassium ferricyanide, M/25,000; potassium nitrate, M/40,000. The potassium salts activate the oyster more effectively than the salts of any of the other normally occurring cations.

Studies of oyster culture in Puget Sound.—An intensive investigation was begun during 1931 in cooperation with the State of Wash-

ington on the problems of the Olympia oyster industry. The Washington State Department of Fisheries and Game constructed an adequate field laboratory at Olympia, purchased a boat, and provided a boatman as well as some of the operating expenses. The investigation is being directed by Doctor Hopkins of the bureau, and it is planned to continue the work for several years.

The primary purpose of this investigation is to develop effective methods of collecting seed oysters in order to rehabilitate and expand the industry. Experiments made during the summer gave highly satisfactory results. The daily abundance of spat obtained in the two most important oyster-producing bays was determined throughout the season and at the same time records of temperature, salinity, pH, and plankton were kept. In Oyster Bay setting took place in two distinct periods, centering, respectively, in June and August. In Mud Bay only one important setting period occurred during June and July. A comparative study is being made of hydrographical conditions in these two apparently almost identical neighboring bays in order to throw light on the causes of these differences and on the factors favorable to setting of oyster larvæ.

The hermaphroditic Olympia oyster carries its larvæ for some time in the mantle chamber. Counts of larvæ showed that an individual may bear up to 350,000 at once, the number depending roughly on the size of the parent. Spawning began early in May and some gravid specimens were found as late as the middle of November, though spawning was most general and profuse in May and early June.

Wire baskets of shells suspended from floats in the deep channels well removed from the main oyster beds obtained a set considerably greater than that on the best seed grounds. Few spat were caught in the surface few inches of water; the maximum number were taken at a depth of 10 to 20 inches, below which the abundance gradually diminished to a depth of 8½ feet, the greatest depth tested.

A modification of the egg-crate filler has been developed as a spat collector for use in the dikes in which Olympia oysters are produced. The new type presents a large amount of horizontal surface, absent in the case of the standard filler, and permits circulation of water through the cells. Most spat were caught on the under horizontal surfaces, few on the upper. Because of the free circulation of the water, the vertical surfaces caught more spat than similar surfaces on the standard filler. Although the new type consists of one-fourth less paper, it caught three times as many spat as the standard.

Investigations in Oregon and California.—During the past year experiments have been conducted by H. C. McMillin in Oregon and California on native, eastern, and Japanese oysters. There is a widespread interest in oyster culture in these States, but a large majority of the persons now engaged in the industry have had no practical experience. For methods of culture and harvesting they rely almost solely on printed matter, written or verbal suggestions, and demonstrations with seed, or young oysters, on various portions of their lands. Because of this some time has been spent on projects intended to illustrate the rudiments of oyster culture to the growers.

A survey of oyster bottoms in Yaquina Bay revealed that this area contains about 200 acres of natural beds, all of which occur below

the low-tide level. The salinity of the bay is affected by local rainfall and is very low in winter and spring.

Observations on imported Japanese seed oysters planted in Elkhorn Slough, Calif., show that this species grows very rapidly. Seed oysters were received from Japan and planted on March 6; they were ready for the market in eight months.

ALASKA RAZOR-CLAM INVESTIGATION

Observations on the razor-clam beds in the Prince William Sound, Copper River, and Bering River areas were made during the season of 1931, under the direction of Seton H. Thompson, by the temporary employees detailed to enforce the regulations in regard to the clam fishery.

Sampling to determine the age composition of the commercial catch was continued. The clams taken were from 5 to 12 years old. It has been pointed out in a previous report that 36.5 per cent of the clams mature in their fourth year, 80 per cent in their fifth year, and all are mature at 6 years of age. Approximately 50 per cent of all clams taken in the commercial fishery in 1931 were older than 6 years, and 80 per cent were mature. More than 55 per cent had spawned more than once.

Other observations included a determination of the time and duration of spawning, and the abundance of clams 1, 2, and 3 years old on the bars. The large number of young clams observed on the bars reflects the present healthy condition of the beds.

The razor-clam fishery in this locality in 1931 was more intensive than in any year since 1927, and the pack was considerably larger than any since 1925. The larger pack was partly due to an extension of 15 days to the fishing season, and partly due to the exploitation of new bars as well as to the increase in the number of clam diggers.

It now appears that with the beds in their present satisfactory condition, the regulations which limit the size of razor clams that can be taken for commercial purposes and provide a closed season of six weeks will afford adequate protection for this fishery.

MUSSEL INVESTIGATIONS AND POLLUTION STUDIES

Investigations of the fresh-water mussel fauna of the interior waters have been continued by Dr. M. M. Ellis, professor of physiology at the University of Missouri, assisted by several investigators. These, together with several professors of the university who collaborate and advise and graduate students who work independently on related problems, constitute the "Columbia (Mo.) unit" of the division in interior waters. Commodious and well equipped laboratory quarters are furnished to the bureau's staff free of charge by the University of Missouri in a new wing of the medical building, acknowledgment of which is hereby gratefully made.

During the spring of 1931 field parties visited the Lake Keokuk district several times to continue observations made during the 1930 survey. Other parties studied streams in northeastern Arkansas, eastern Kansas, and north central Texas. After reoutfitting the U. S. Quarterboat *348* as a floating laboratory at Keokuk, Iowa, a

field party of 11 went aboard in June and continued the survey work begun in 1930. Through the cooperation of the United States Engineer Corps this party covered the Mississippi River from Lake Keokuk south to Cairo, Ill.; the Ohio River from Cairo, Ill., to the mouth of Green River above Evansville, Ind.; and the Tennessee River from its mouth at Paducah, Ky., to the Hiwassee River, some 40 miles above Chattanooga, Tenn. During this survey many tributary streams were examined and an extensive study made of the Lake Wilson (Ala.) region. The boat returned to Keokuk, Iowa, the last of September and the collections were sent to the laboratory at Columbia, Mo., for analyses and review.

After the quarterboat was tied up for the winter, parties working by auto continued field work in the Lake Keokuk region and north on the Mississippi River to Winona, Minn.; also in northern Arkansas and in the Lake Worth region near Fort Worth, Tex. During the last of December field parties working south through Missouri, Arkansas, Tennessee, Mississippi, Louisiana, and Alabama studied the St. Francis, the White, the Black, the Pearl, the Tombigbee, the Warrior, and the Tennessee Rivers and their tributaries.

POLLUTION STUDIES

In view of the fact that the 1930 survey on the Mississippi River demonstrates that erosion silt is a factor of major importance in many fisheries problems in the inland river systems, particularly problems in which pollution is involved, the pollution studies made by this unit have centered around erosion silt during the past year. In both the field work and the laboratory studies effort has been made to secure qualitative and quantitative data on the effect of erosion silt alone and as a carrier of other substances. The results of the investigations to date may be summarized as follows:

Mass of silt.—The amount of silt already deposited on the bottom of the streams studied exceeded even that which the 1930 survey suggested would be found. In certain places the silt deposit exceeded 10 feet, and in one locality on the Tennessee River, 27 feet in thickness. Behind both temporary and permanent obstructions to stream flow the deposition of erosion silt was proceeding rapidly in all of the streams studied, soundings regularly showing deposits from 1 to 4 feet in depth.

Mechanical action of silt.—The field work demonstrated that wherever the current of the water is slowed sufficiently not only is the bottom covered with silt deposits but a colloidal suspension of silt particles was to be found just above the top of the semisolid silt, so that in many places there was a progressive gradation from the muddy river water through a thick colloidal suspension to the semisolid mass of deposited silt. Laboratory tests showed that the top layers of the deposited silt and the bottom layers of the suspension supported very little weight, so that even small animals mired down readily in the silt deposit. From the field work it was noted that 6 inches of erosion silt, or frequently less, was sufficient to completely change the bottom fauna and to eliminate most of the sedimentary animals usually found at the bottom of unpolluted streams.

Erosion silt in suspension.—A special apparatus making use of photoelectric cells was devised for the measurement of the amount of material in suspension in the various waters studied. By means of this instrument readings could be made both rapidly and very accurately, so that a large amount of data of this sort was assembled during the past year. These studies show that the erosion silt in suspension materially effects the light transmission into the river water, thus materially changing the river as a habitat for certain microorganisms and other animals even before the silt has settled to the bottom. The elimination of light by the silt suspension amounts to over 90 per cent in the first 25 millimeters of water, and silt suspension was found to be selective against certain parts of the spectrum. The greatest penetration through the silt suspension was made by the orange-red rays, although only a small amount of this light was transmitted. The alteration of light penetration by the suspended silt in river water, particularly in the larger bodies of water which are impounded behind the power dams on the Mississippi, produced changes in the plankton, thus altering the basic unit in the food chain of the aquatic fauna. Sudden and abrupt changes in the plankton count followed sudden rises in the amount of suspended matter present in these waters.

The erosion silt in the water also produces definite changes in the heat conduction and heat radiation of the water; and since the dissolved oxygen varies in inverse direction with the temperature, these changes in the heating and cooling of the water attendant on the presence of erosion silt have important bearing on the respiration of the river and therefore on the available oxygen for the animals living therein.

Erosion silt and oxygen demand.—Because of the colloidal nature of erosion silt, it carries down with it particles of organic material in various stages of decomposition. Decomposing carcasses of animals and masses of rotting vegetation are also readily covered by the silt deposits and are thus cut off from free access with the water of the stream. Under these conditions the rate and character of the decomposition of the organic material carried down by the silt or buried under it is altered and enormous quantities of gas produced in some places. This condition creates a high oxygen demand in the top layers of the deposited silt, resulting in complete change of the bottom fauna, reducing it to those few forms capable of withstanding conditions of low oxygen and water polluted by products of decomposition. This oxygen demand is not only evident in the quieter portions of the rivers but also shows in the main streams themselves. At the junction of the Ohio and Mississippi Rivers below Birds Point, for example, the oxygen demand of the Mississippi River water loaded with polluted silt from the St. Louis district was sufficient to reduce the entire volume of Ohio River water, which had a much higher oxygen content than the Mississippi, to the Mississippi River level in less than 12 miles.

Erosion silt and bacteria.—Comparative bacteriological studies on the erosion silt and organic deposits at the bottom of the river as compared with bacterial counts in the main stream itself show definite differences in the character of the bacterial flora in the silt layers, and in many places an excessively high bacterial count, due

to the combination of erosion silt and organic waste which the erosion silt carries along from the sewerage and wastes introduced into the river by cities and manufacturing plants. Laboratory tests carried forward under controlled conditions show the decomposition of various organic substances mixed with erosion silt to proceed at a slower rate and to produce different end products with greater oxygen demands than the decomposition of these same substances in plain water alone.

Comparison of silts.—Chemical studies and electrical and physical measurements on erosion silts from various parts of the Mississippi Valley have been made and technical classifications of these silts obtained, which permit comparisons of the erosion silt action through the Mississippi River system.

Erosion silt and industrial pollution.—Detailed laboratory studies on the relation of erosion silt to industrial pollution, particularly sulphur, acid wastes, and heavy metal wastes, are in progress, continuing the work on sulphur, acid pollution, and arsenic begun last year. These studies so far indicate that the erosion of silt is both a carrier and reservoir for many of these substances, and the presence of erosion silt in many cases augments the detrimental action of these substances on living organisms.

MUSSEL INVESTIGATIONS

The overwhelming of so many mussel beds by the silt deposits is so evident in the Mississippi and Tennessee systems that in view of the proposed modification of many of the inland streams for navigation and hydroelectric plants careful attention has been given to the condition of the existing mussel beds wherever found throughout the field work, and extensive collections of all species, both commercial and noncommercial, were made for survival and population studies. Upward of 10,000 shells have been examined in the last year and detailed statistical studies made of the age, rate of growth, weight, thickness, and of the physiological condition of the animal itself at the time of capture for comparison with the physical and chemical data obtained in the field at the habitat from which the individual mussel was taken. In this way it has been found that the natural replacement at present of fresh-water mussels of the commercial species in the Upper Mississippi River is far below that required for even the maintenance of the existing beds. The statement is also true to a large extent for the portions of the Ohio and Tennessee systems studied. These facts have been set forth in the preliminary report (Fisheries Circular No. 7, 1931). With the depletion of the mussel beds of these major streams almost a certainty if existing conditions continue, detailed physical, chemical, and biological studies have been made in the most favorable habitats found with a view to a duplication of such conditions in controlled waters. From the data obtained experimental raceways have been planned and experiments will be started this spring in the Lake Worth area with a view to duplicating the best conditions for mussel growth and the rearing of large numbers of mussels in small areas.

The transfer of attention from the reestablishment of the mussel beds in the natural habitats in the larger rivers, as the Mississippi

and Tennessee, to the production of artificial beds in controlled habitats has made necessary extensive studies on the physiology of the fresh-water mussel, particularly feeding and general reactions, because of the paucity of literature on these subjects bearing on the particular problems in hand. Consequently, mussels from various parts of the United States have been placed under observation in the laboratories of the unit at Columbia, Mo., and detailed physiological observations made on the movements, respiration, heart action, feeding, hibernation, and growth of these animals. From these studies the oxygen requirements, food choices, food elaboration, and winter habits of these animals have been followed preparatory to placing them under observation in the controlled habitats out of doors. Work reported last year has been confirmed, namely, that contrary to the popular belief most of the mussels prefer clean water and are very sensitive to changes in their environment, particularly such changes as are produced by erosion, silt, sewage pollution, and industrial wastes. It has been found that the animals can be fed readily with several inexpensive substances and the general condition of the mussel improved, as shown by physiological observations on the activity of the animal itself and by the amount of food stored in the living animal. All of these laboratory observations are to be used as scientific backgrounds for the field work at the propagation station.

Observations on glochidia and spawning time of several species of fresh-water mussels have been extended during the past year. The peculiar spawning habits of the Arkansas fanshell have been worked out in considerable detail and constitute a unique type in the known methods of spawning of fresh-water mussels. Gravid yellow sandshells have been carried throughout the winter and observations on the needs of gravid individuals made to extend the knowledge of handling of these animals for breeding stock.

A census of the parasites, diseases, and injuries of the fresh-water mussels have been carried on through the year, as all parasites found have been preserved and the physiological and pathological conditions of each mussel studied noted. As is well known, a water mite is perhaps the commonest parasite of fresh-water mussels in the United States, and the depredations of this parasite have been followed in the field work throughout the year.

Limnological observations.—Various species of animals have been used as indicators of river conditions, and consequently collections of plankton, shore animals, and bottom forms have been made wherever possible throughout the course of the field work. These collections are discussed in the forthcoming report on the 1931 survey.

ACTIVITIES OF THE FISHERIES BIOLOGICAL LABORATORIES

WOODS HOLE, MASS.

The bureau's laboratory at Woods Hole, under the direction of O. E. Sette, has furthered the scientific investigations of the bureau in supplying facilities for experimental work on oyster problems, fish tagging, rate of development of mackerel eggs, and rearing of larval fish. The station also served as a base for the collection of data on the local mackerel fishery; for studies on planktonic fish eggs and

larvæ; and for the tagging of scup. With the collaboration of the fish-cultural staff, some 4,000 flounders caught incidental to hatchery operations were tagged at the station; also more than 300 brood cod.

Due to the limited funds available for station maintenance, the buildings and equipment have not kept pace with the requirements of the bureau's program. Particularly urgent is the replacement of the collecting vessel and the station launches with more seaworthy craft capable of operating appropriate fishing gear. The station's usefulness would also be greatly increased by weatherproofing the buildings, to permit occupancy for experimental work during the winter and early spring periods, which is the only time that early life-history material on certain important food fishes is available.

In accordance with the bureau's long-established policy of encouraging independent research in marine biology and related subjects, the facilities of the laboratories at Woods Hole, Mass., were made available to a number of investigators from various educational institutions. Personnel so accommodated at Woods Hole included: Dr. Robert P. Bigelow, Massachusetts Institute of Technology, stomatopoda of the *Albatross* Philippine expedition; Frank A. Brown, Harvard University, mechanism of color changes in the shrimp; Dr. N. A. Cobb and assistants, Department of Agriculture, nematodes; Paul S. Conger, United States National Museum, diatoms of the Woods Hole region; Kendall W. Foster, Harvard University, color changes of Fundulus; Dr. F. G. Hall, Duke University, respiration of fishes; Charles W. Hooker, Duke University, respiration of fishes; Mrs. Helen W. Imlah, Radcliffe College, effect of thyroxin on the ascidian larvæ; Dr. George B. Jenkins, George Washington University, vertebrate embryology; Dr. Edwin Linton, University of Pennsylvania, helminth parasites of fishes; W. G. Lynn, Johns Hopkins University, embryology of the nervous system of reptiles; Dr. J. H. Sandground, Harvard University, helminth parasites of fishes; G. W. Taylor, Princeton University, respiration of luminous bacteria and permeability in starfish eggs; Sam R. Tipton, Duke University, respiration of fishes; Dr. C. B. Wilson, State Normal School, Westfield, Mass., copepods of the Carnegie expedition.

BEAUFORT, N. C.

Research.—The Beaufort laboratory under the direction of Dr. S. F. Hildebrand until July 1, 1931, and under Dr. Herbert F. Prytherch after that date, is being developed as a research center in the South Atlantic region for marine studies in both pure and applied biology. The chief investigations conducted here at present by the bureau's staff, as reported elsewhere, deal with the biology and cultivation of the oyster, the copper content of inshore coastal waters, the development and distribution of the shrimp, and the propagation of the diamond-back terrapin. Laboratory facilities have been furnished to independent research workers from other institutions who have engaged in the following studies: Dr. H. V. Wilson and Joseph H. Pratt, jr., of the University of North Carolina, cellular behavior in the embryonic development of hydroids (Pennaria), the early development of sea urchins (Toxopneustes), and the regeneration of young ascidians (Styela); Dr. Bernard

Steinberg, director of the Toledo Hospital, the effect of bacterial toxins on various marine forms; Dr. Ezda Deviney, of the University of North Carolina, regeneration of Ascidians, particularly with respect to the specific cells in Perophora that are of greatest importance in this process; Dr. C. D. Beers, of the University of North Carolina, structure and life history of two colonial protozoa (Vorticellidae); Rebecca Ward, of Judson College, invertebrate marine fauna of this region and early development of several Echinoderms; Dr. Bert Cunningham, of Duke University, relationship of temperature to the rate of embryonic development of diamond-back terrapin.

The facilities of this station were also utilized by the investigators of the United States Chemical Warfare Service, who tested the value of various oils as a preventive of the destruction of wood by marine borers. In cooperation with the Eastman Kodak Co. an educational motion-picture film was prepared showing photomicrographic studies of the development of the oyster and the scientific methods of oyster cultivation that have been developed by the Bureau of Fisheries.

Terrapin culture.—The propagation and distribution of the diamond-back terrapin is meeting with greater success each year. In the spring of 1931 about 5,500 year-old terrapins from the 1930 brood were turned over to the North Carolina Department of Conservation and Development for liberation in the coastal waters of this region. The 1931 hatch, amounting to 12,152 young, has exceeded all former records and is over 25 per cent greater than the largest previous hatch of 8,931 in 1928.

Growth studies and feeding experiments with the 1930 brood were made during the first half of the year by Dr. Samuel F. Hildebrand. Several of these experiments extended over three seasons and yielded noteworthy results that are of value in the culture of this species. Of the various foods and mixtures of foods used, oysters fed alone produced the most rapid growth in the 1930 brood, with a mixture of oysters and fish a close second. Fresh fish fed alone promoted a fair rate of growth and is the cheapest and most easily prepared terrapin food available at Beaufort. It was shown again that salt water is a slightly better medium than fresh water for young terrapins in the brooder house.

Various diseases develop during the period that the young are cared for in the rearing house and greatly reduce the total production of year-old individuals. The disease, designated as "sores," for want of a better term, which has been present among young winter-fed terrapins from year to year was rather more prevalent than usual in the 1930 brood and in a few tanks reached epidemic proportions. Among 7,054 animals taken care of in the brooder house, 6 per cent died of this disease. "Soft shell," associated with a failure to feed and to grow, caused 14.2 per cent of deaths, and all other causes 1.6 per cent, making a total death rate of 21.8 per cent. This is near the average death rate for winter-fed animals from 1920 to 1929, inclusive.

In rearing the large 1931 brood particular attention has been given to these diseases and studies made to determine their cause and effective method of control. Shortly after the young were transferred to the rearing house there appeared a serious outbreak of the

tail-and-foot disease, which in the past has destroyed from 17 to 35 per cent of the total brood. Experiments carried out by Dr. H. F. Prytherch for the purpose of finding a practical cure for this malady show that copper is very effective not only in checking the disease but also in permitting regeneration of the infected tissues. In the early fall the disease soon assumed epidemic proportion and appeared in the form of rapid growing lesions of the tail, feet, skin, and eyes of the young terrapins. Various methods of disinfection were tried. The rearing troughs were regularly disinfected with various concentrations of formalin, and a strong solution of salt brine, while the infected terrapins were isolated and treated with dilute solutions of copper sulphate, aluminum sulphate, formalin, and sodium thiosulphate.

In the two control lots there was a loss of over 94 per cent of the terrapins after a period of 10 weeks. On the other hand, those treated with copper sulphate showed in the same length of time a total loss of only 8 per cent. In the aluminum sulphate, formalin, and sodium thiosulphate solutions there were losses of 20 per cent, 15 per cent, and 22 per cent, respectively. Though each of these four solutions checked the rapid growth of the disease, its complete elimination was evident only in the lot of terrapins treated with copper sulphate. A careful examination on November 10 of the terrapins treated with copper showed that every single individual had completely recovered from lesions affecting the eyes, tail, and feet and had grown a new layer of skin over the injured tissues.

Diseased terrapins from the numerous rearing compartments were also placed in a large copper-lined tank in the hope that this might prove a practical method of combating the disease. The animals placed here exhibited remarkable improvement in a few days and showed after a period of three months a loss of only 13 out of a total of 146 infected individuals. Since metallic copper apparently gave off enough free ions to produce a beneficial effect, a small piece of sheet copper 2 inches square was placed in each rearing compartment. Noteworthy results have followed this simple procedure, as evidenced by the fact that the loss of young terrapins has steadily decreased, from 103 in September to 27 in October, 21 in November, and only 8 in December. The records of terrapin mortality for 1930 are much higher than for the present year and show a loss of 41 out of a total of 7,028 in November and 26 out of a total of 6,987 in December, while for the past two months there has been a loss of only 21 out of 12,022 in November and 9 out of 12,001 for December. It is probable that the rapid recovery of the terrapins in the presence of copper is due not only to the bactericidal action of this element but also to a possible deficiency of copper in the diet for blood formation as a result of keeping the animals in confinement.

A report covering all terrapin-cultural activities carried on since the preparation of the last general report in 1927 (Review of Experiments on Artificial Culture of Diamond-Back Terrapin, by Samuel F. Hildebrand, Bulletin, U. S. Bureau of Fisheries, Vol. XLV, 1929 (1930), pp. 25 to 70), was prepared during the year.

Shore fishes of North Carolina.—The studies of the development of fish eggs and young fish, undertaken several years ago, was con-

tinued actively by Dr. Samuel F. Hildebrand and Louella E. Cable at the Beaufort Laboratory. Field work was continued, and the collections for study were considerably augmented. In the laboratory the study and identification of specimens was continued, and a special effort was made to build up for different species complete series showing all the stages in the development from the egg, or very small larvæ, to the adult. Descriptions and drawings for several species, together with notes on their spawning habits, rate of growth, food and feeding habits, and commercial importance, were prepared.

APPROPRIATIONS

Under the terms of the act of May 21, 1930, known as the Five-year construction and maintenance program for the Bureau of Fisheries, additional appropriations of funds for the division of scientific inquiry have been made. During the fiscal year ending June 30, 1931, $262,000 in round numbers was provided for the scientific work of the division. For the remaining half of the year, appropriations for the fiscal year 1932, totaling approximately $322,500, were available. These figures represent the combined appropriations from various accounts except funds spent for vessel operations in connection with scientific work. The funds were allotted in the various sections of the country as follows: For fishery investigations in the Atlantic and Gulf coast areas, 23 per cent; for the Great Lakes and interior lakes, 8 per cent; for the Pacific coast, 17 per cent; for investigations in the interest of fish culture throughout the country, 15 per cent; for shellfish investigations, including oyster cultural studies, mussel propagation, and pollution studies, the shrimp investigations, and the operation of the Beaufort (N. C.) Fisheries Biological Laboratory, devoted chiefly to oyster-cultural studies during the last half of the year, 23 per cent; for studies on the conservation of fish by means of screens and ladders, 6 per cent; for the operation of the central laboratory in Washington, administrative costs, and supplies furnished to field investigations through the Washington office, 7 per cent.

As was pointed out in the previous report of this division, the greatest obstacle to the orderly development of a comprehensive program of fisheries research, adequately covering all sections of the country, lies in the failure to provide for increased vessel operations. Although small craft have been added to the bureau's fleet for inshore-fishery studies, in some localities, in the North Atlantic particularly, investigations are being hampered by lack of adequate vessel facilities. Nevertheless, it is anticipated that, pending the securing of a seagoing vessel suitable for high-seas investigations, some improvement in existing facilities can be made during the fiscal year from funds already appropriated which will in a measure compensate for these deficiencies.